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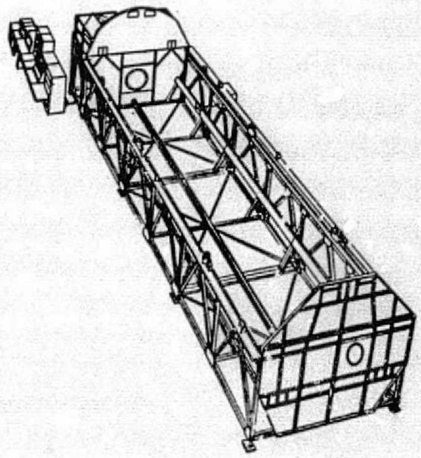

SHUTTLE PAYLOAD INTERFACE VERIFICATION EQUIPMENT STUDY
VOLUME I EXECUTIVE SUMMARY

APRIL 1976

NASA CONTRACT: NAS9-14000 CCA 140 REV. 1

PREPARED BY:
SHUTTLE PAYLOAD
INTERFACE PROJECTS GROUP

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H. E. EMIGH
DIRECTOR
STS/PAYLOAD INTEGRATION

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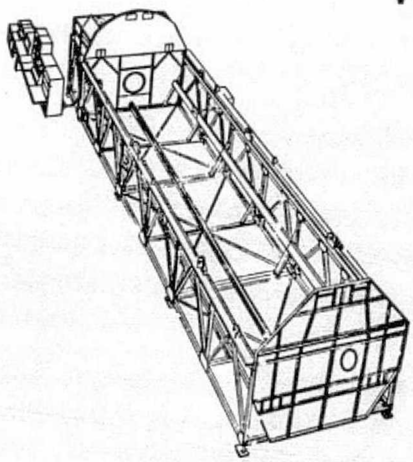

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FOREWORD

This document is a contractual requirement of NAS9-14000, CCA 140 Revision 1 and is provided in response to the contract. The study was conducted by the Space Division of Rockwell International for the Johnson Space Center of the National Aeronautics and Space Administration. It is published in four volumes:

Vol. I	Executive Summary
Vol. II	Technical Document - Part 1 Technical Appendices - Part 2
Vol. III	Specification Data
Vol. IV	Project Plans

TECHNICAL REPORT INDEX/ABSTRACT

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DESCRIPTIVE TERMS

Shuttle	Preliminary Design	Data Management
Payloads	Operators Console	Computer
Spacelab	Mission Station	Heat Exchanger
P/L Interface	On-Orbit Station	Development Plans
P/L Interface Verif.	Payload Station	Schedules
Avionics	Electrical Power	
Payload Integration	Communications	

ABSTRACT

Single and mixed payloads must be integrated into the Shuttle Orbiter within the 160 hour turnaround requirement for the Shuttle system. In order to accomplish this integration process some off-line integration capability is required. This report is a preliminary design analysis of a "stand alone" (no facility GSE support required) payload integration device (IVE) capable of verifying payload compatibility in form, fit and function with the Shuttle Orbiter prior to on-line payload/Orbiter operations. The IVE is a high fidelity replica of the Orbiter payload accommodations capable of supporting payload functional checkout and mission simulation. A top level payload integration analysis developed detailed functional flow block diagrams of the payload integration process for the broad spectrum of P/L's and identified degree of Orbiter data required by the payload user and potential applications of the IVE.

This work was performed for Johnson Space Center of the National Aeronautics and Space Administration under contract NAS9-14000 CCA 140 Rev. 1.

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1.0 INTRODUCTION

This document is a summary of the Shuttle Payload Interface Verification Equipment (IVE) Study conducted by the Space Division of Rockwell International for the NASA. It describes the background and intent of the study, study approach and philosophy covering all facets of Shuttle payload/cargo integration. The study covers integration requirements, preliminary design of the Horizontal IVE, Vertical IVE concept, and IVE program development plans, schedule and cost. The study also includes a payload integration analysis task to identify potential uses of the IVE in addition to payload interface verification.

The primary objective of the study was to define a low cost simulation of the Orbiter side of the standard interface to the payload as defined in the JSC 07700, Vol. XIV. This device was to meet the off-line Shuttle payload integration requirements at the KSC launch site as well as support the functional testing and acceptance testing of the payload at the payload user locations. The payload integration device described (IVE) is a high fidelity replica of the Orbiter payload accommodations providing the capability to verify the form, fit and functional compatibility of the payload to the Orbiter and also support payload development.

A design analysis of the IVE was conducted to a preliminary design level. Configuration drawings were generated showing the design details of the IVE. Subsystem functional block diagrams were developed identifying major elements and the physical and functional interfaces to make up the IVE system. Design trades were conducted to evaluate (1) design commonality for Horizontal and Vertical IVE configurations, and (2) Orbiter flight (design) avionics vs a mix of Orbiter design (non-flight qualifiable hardware) and commercial test equipment.

The IVE potential for other applications in support of the Shuttle to payload integration process was investigated. Areas of investigation in addition to payload interface verification included use as: a design tool, a manufacturing aid/production tool, support ground operations procedures development and a training aid for ground and flight crew.

Program planning data was generated to provide the basis for cost estimates and to initiate the next phase of IVE development. Project planning data includes: management, configuration control, quality assurance, make or buy, subcontractor management plan, acceptance test plan and a NASA proposed operational support plan. An IVE master schedule was developed identifying the major elements of the IVE and their lead times. A cost estimate was generated covering non-recurring and unit costs for the major elements and project functions.

2.0 BACKGROUND

The objective of the Shuttle payload integration processes is to bring the Shuttle and payload programs together to achieve an acceptable level of mission success with minimum cost and risk to both programs. The Space Shuttle transportation system operator, and the various payload programs (including the payload carrier developer, and payload developers, the carrier payload integrators, and the carrier payload operators) have to develop an implementation process and the necessary tools to accomplish this objective.

The integration process must consider single and mixed payloads (cargo) for installation in the Shuttle Orbiter Payload bay. This integration process may occur at the launch site, or at other payload or carrier users sites. In the Shuttle Program approach, the integration of payload into the Shuttle system has been limited to the idea of what is necessary to install a payload into the Orbiter payload bay. The Shuttle program assumes that the payload, like any other element of the Shuttle system, has been checked out prior to mating with the Orbiter in order to meet the 160-hour turnaround requirement for the Shuttle system. The time allocation for payload integration during the on-line flow was limited; consequently, the on-line tasks were restricted to the physical mating, continuity check of the electrical and signal interfaces, leak check of the fluid system, and final servicing prior to launch.

If a problem occurs during the integration process, the on-line timeline will be extended or at least placed in jeopardy and the cost per flight (ground operations portion) may increase.

From both the Shuttle Program point of view and the Payload Program point of view, there appears to be a requirement for an off-line integration capability in order to avoid extending on-line P/L integration timelines. Prior to the start of this study, this capability was identified as (1) a Shuttle Integration Device (SID) by KSC, (2) a Shuttle base simulator by GSFC, and (3) an Orbiter/Spacelab Simulator by MSFC.

Supporting the needs of these various organizations, NASA/KSC/Goddard/MSFC, and JSC jointly sponsored a study to define a common design low cost simulation device to replace the above identified integration devices. The study was initiated with Rockwell International under CCA 140 to the NAS9-14000 contract. This study was identified as the IVE study - "IVE" standing for "Interface Verification Equipment." MSFC transferred funds (Figure 2-1) and provided Spacelab program requirements. The study was expanded with NASA and DoD funding also shown in

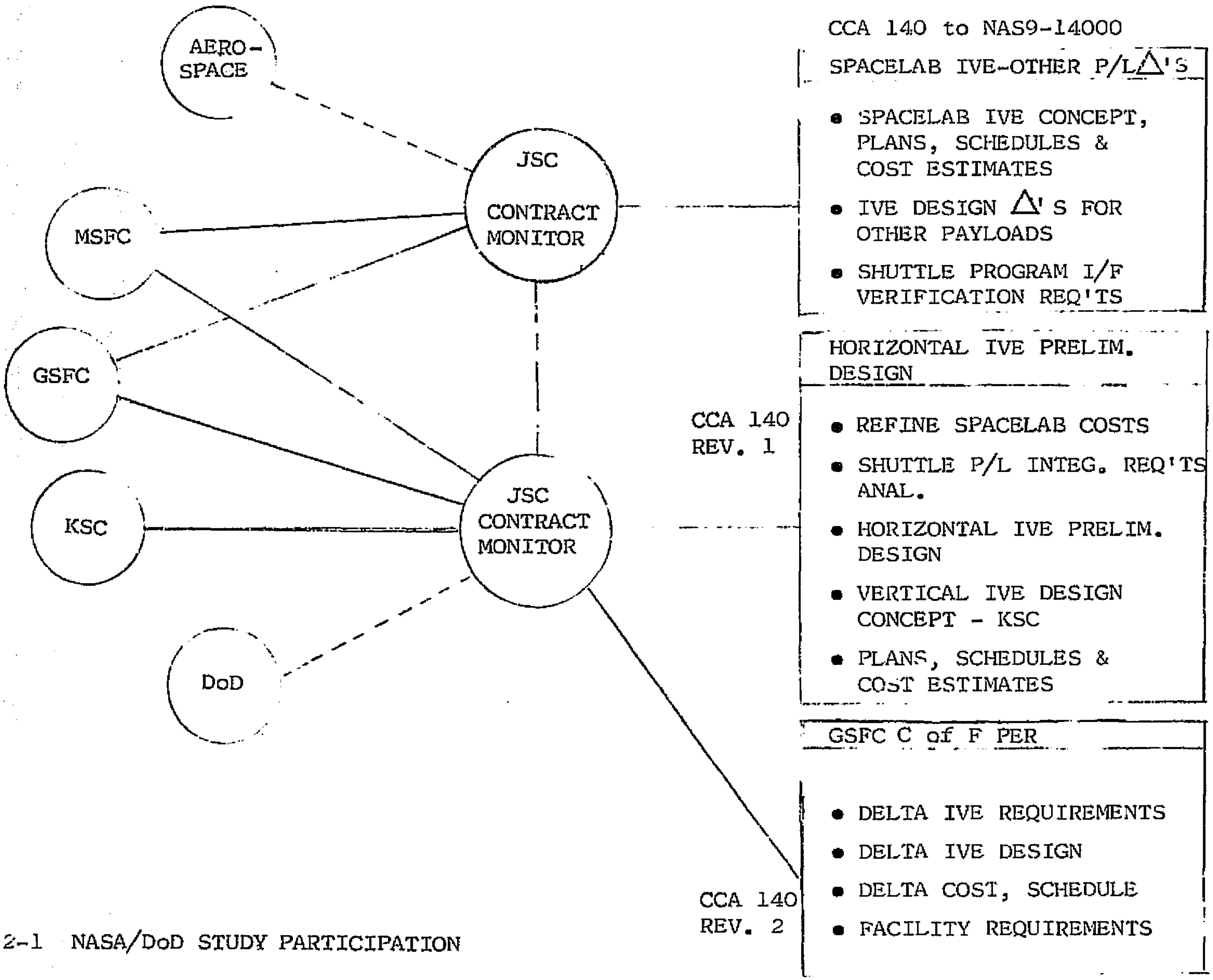

FIGURE 2-1 NASA/DoD STUDY PARTICIPATION

Figure 2-1 to provide a broader treatment of Shuttle/Payload interface verification. NASA/GSFC/KSC and Aerospace (for DoD) provided their unique requirements. NASA/JSC Shuttle Program Office supported the study to develop payload to Shuttle interface verification requirements (inputs to the "Space Shuttle System Payload Interface Document, Vol. I, "General Approach and Requirements," document No. JSC 07700-14-PIV-01.

The initial study tasks, approach logic and outputs are shown in Figure 2-2. Upon completion of the initial study, MSFC provided additional funding (32K) to update and refine the Spacelab IVE design and provide more detailed IVE specification and cost data (Tasks 1 and 2 of the CCA Rev. 1 study as shown in Figure 2-3). GSFC and KSC provided funding to conduct a preliminary design of the Horizontal IVE to reflect the broad spectrum of payloads. In addition GSFC requested an analysis be performed to define Shuttle Payload Integration functional flow block diagrams (reflecting the broad payload spectrum) to identify other potential applications of the IVE. KSC requested a specific task to develop a vertical IVE concept using the horizontal IVE as a starting point and determine required design deltas.

A separate study (CCA Rev. 2) was funded (17K) by GSFC to provide inputs to a Preliminary Engineering Report for C of F (cost of Facility) requirements. Data included design deltas for a single IVE to be used in both a horizontal and vertical position and incorporate capability for IVE to perform data processing to support payload functional checkout and payload mission simulation in addition to I/F verification.

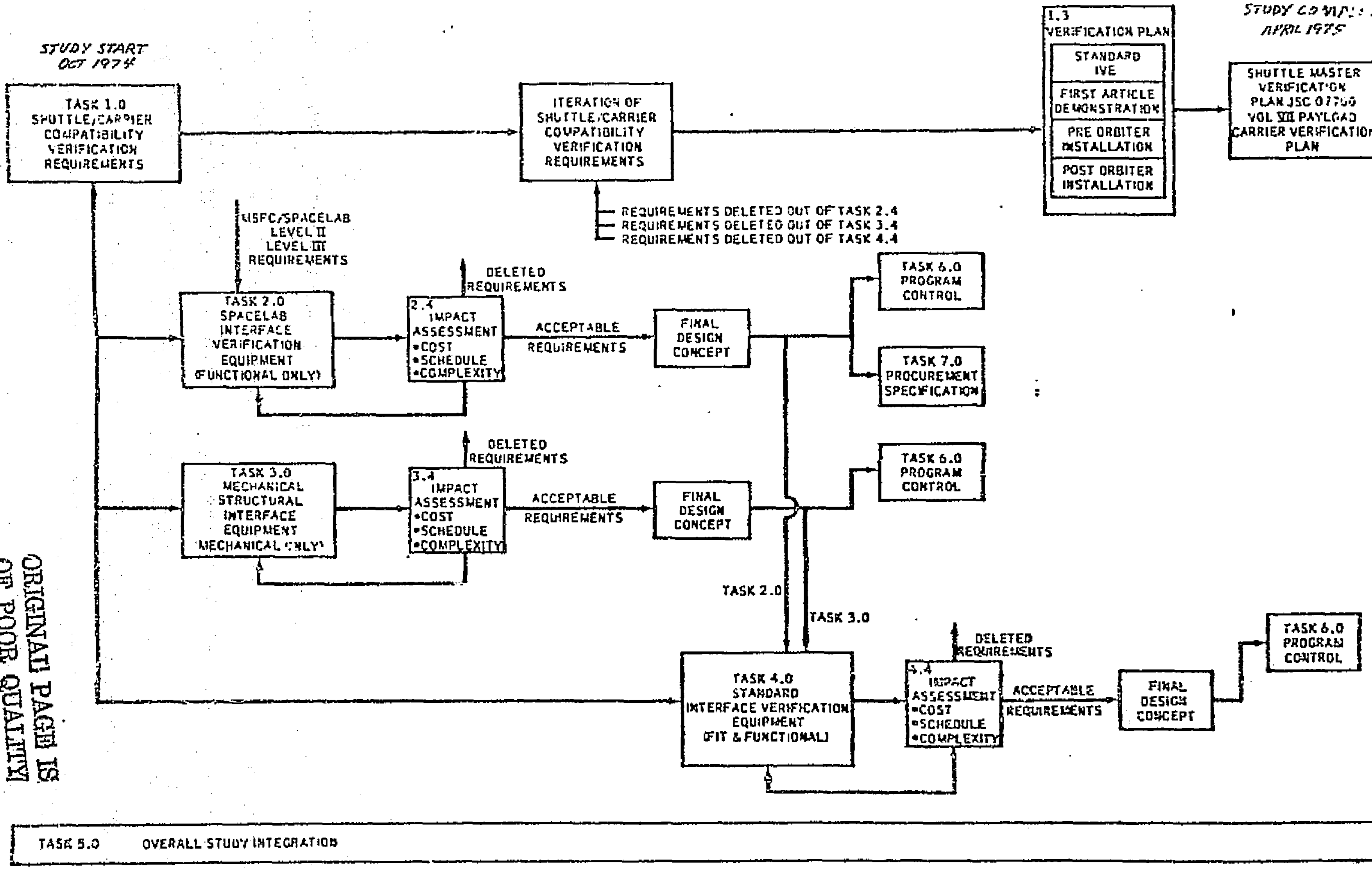

FIGURE 2-2 IVE INITIAL STUDY LOGIC (CCA 140)

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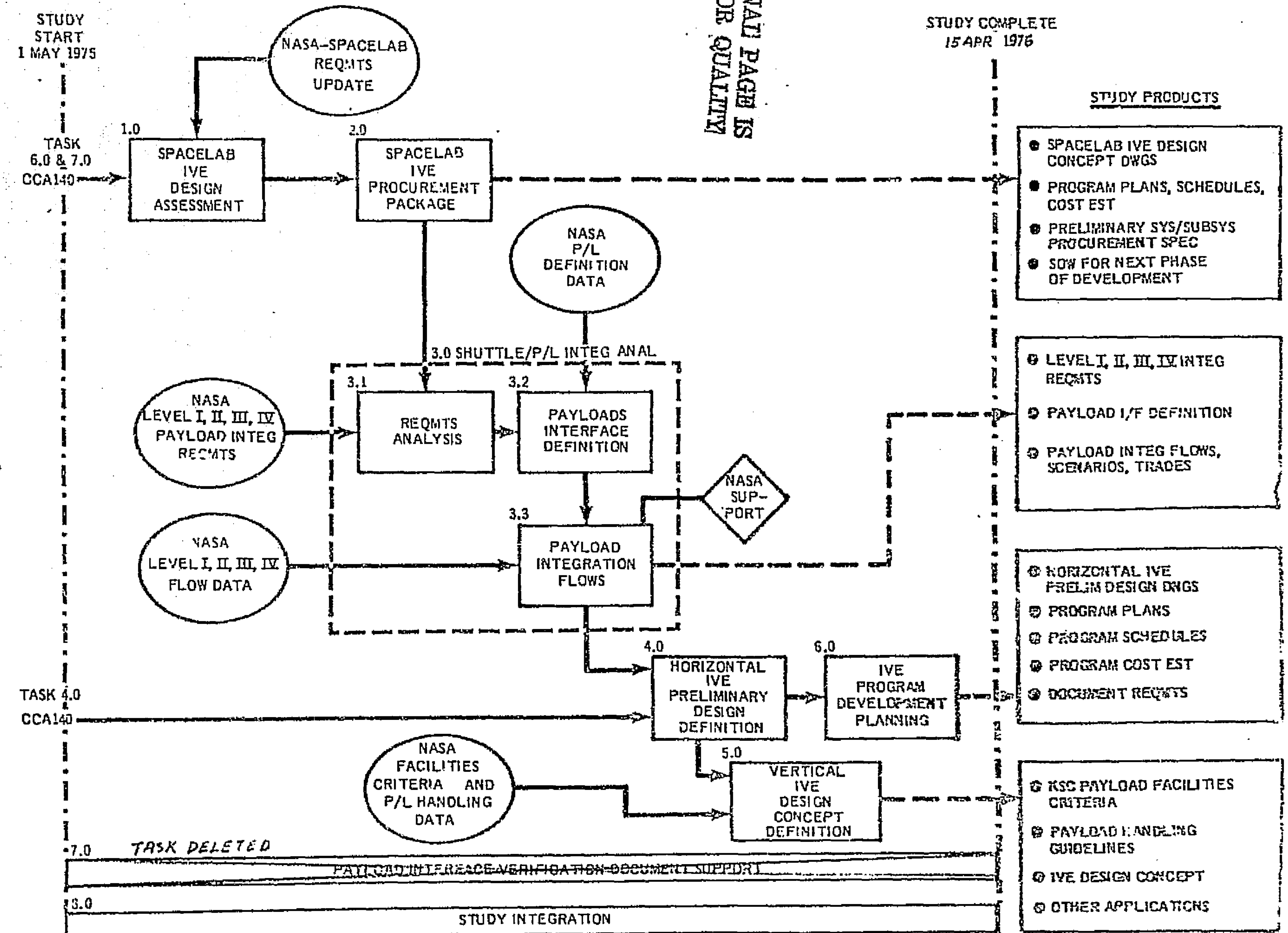

FIGURE 2-3 IVE EXTENDED STUDY LOGIC (CCA 140 REV.)

3.0 REQUIREMENTS AND CONSTRAINTS

3.1 IVE REQUIREMENTS

The functional requirements impacting the design and performance of the IVE are grouped into three categories as follows:

1. Payload Requirements - representative user requirements as defined by NASA/MSFC/GSFC and KSC and DoD.
2. Shuttle Program (JSC) Requirements - requirements imposed on the user to verify payload compatibility with the Orbiter.
3. Space Transportation System Requirements - requirements imposed on the Shuttle Program and the payload users to assure cargo compatibility with the Orbiter.

3.1.1 Payload Requirements

The payload requirements governing the design of the IVE are described in detail in the following documents:

- Spacelab Specification, Performance, Design and Verification Requirements for the Shuttle Interface Verification Equipment, NASA/MSFC 45A00000, March 18, 1975.
- GSFC Requirements for the Interface Verification Equipment (IVE) Study, Letter dated November 19, 1974.
- KSC Hardware Requirements for Interface Verification Equipment, KSC Letter SP-PAY-9-75, January 23, 1975
- Interface Verification Equipment (IVE) Study Extension, Task 5.0 Vertical IVE Design Definition, KSC Letter and dated August 15, 1975.
- Interface Verification Equipment (IVE) - Summary Information, Aerospace Letter 74-2610.5-H146 dated 24 October 1974.

Payload requirements having a major impact on the IVE are summarized in Table 3.1. Also included in Table 3.1 are identification of the source of the requirement and explanatory comments.

3.1.2 Shuttle Program Requirements

The Shuttle Program (NASA/JSC) requirements imposed on the

Table 3.1 PAYLOAD REQUIREMENTS FOR IVE

IVE REQUIREMENTS	COMMENT/SOURCE
PAYLOAD USER	
1. Provide a functionally and dimensionally accurate replica of the Orbiter payload accommodations interfaces.	Verify form, fit, function at Orbiter to payload interfaces.
2. Support payload DDT&E and acceptance testing.	Spacelab payloads, multimission modular spacecraft (GSFC), Spacelab (MSFC), DoD payloads (Aerospace).
3. Non-facilitized, "stand alone" (no support GSE), independent operation	Spacelab (MSFC), all payloads (KSC) facility availability/capability not known during study.
4. Modular Design (individual piece usage, combined assembly usage).	Facilitate ease of handling, transportation, flexibility of usage (MSFC, GSFC, KSC).
5. Verify all Orbiter/payload interfaces over the allowable flight range of values.	MSFC, GSFC.
6. Accommodate installation and removal of payload unique optional equipment.	Facilitate installation and self-verification readiness of all optional equipment.
7. Impose no design requirements on the payload in addition to those imposed by the shuttle.	All payload users.

Table 3.1 PAYLOAD REQUIREMENTS FOR IVE (Cont)

IVE REQUIREMENT	COMMENT/SOURCE
8. Automated (with manual) operational mode.	All payload users.
9. Do not preclude use of vertical IVE in horizontal position.	KSC
10. Payloads installed/removed using overhead crane with payload handling equipment.	All horizontal payloads vertical IVE (KSC).
11. Compatibility with Orbiter EMC requirements, not be source of radiated and conducted interference.	All payload users.
12. Operational self test capability and certification at user site.	All payload users.
13. Compatibility with class 100k clean environment.	All payload users. DoD requirements not known at time of study.
14. Workstands not part of IVE. IVE shall not preclude operation with workstands.	Maintain clean sidelines in IVE design.

IVE include:

1. Simulate all Orbiter payload accommodations as defined in the Space Shuttle Payload Accommodations Document, JSC 07700, Vol. XIV.

2. Orbiter payload interfaces requiring verification and methods of accomplishment are as defined in the Space Shuttle System Payload Interface Verification Document, Vol. I, General Approach and Requirements, Document No. JSC 07700-14-PIV-01.

During the study, exception was taken to Item 2 above due to the (1) delay in incorporation of a change in the design interface baseline into Vol. XIV, and (2) lack of definition of a baseline interface. As the Orbiter design was baselined at the Level III Engineering Review Board the IVE design was changed accordingly. Where Payload Interface baseline did not exist, the most promising (at the time) design approach was used to provide planning data for scheduled cost estimates.

3.1.3 Space Transporatation Requirements (STS)

The STS required that the IVE be capable of supporting the integration and verification of the multiple payload elements (mixed payloads) which institute Orbiter cargo.

3.2 IVE DESIGN CONSTRAINTS

Limitations and constraints impacting the IVE design during this study include:

1. Following interface areas have been excluded from the IVE design concept due to cost and other existing or planned Shuttle developments:

   a. Software Validation/Verification - IVE does not employ Orbiter General Purpose Computer (GPC). IVE may support software development by checking software sizing and timing.

   b. EMI/EMC - limited to payload generated conducted interference. No other IVE capability is planned.

   c. RF Interface - no capability planned for IVE to verify RF interface (payload interrogator/detached payload).

d. Static Device - no structural dynamics planned for the IVE.

e. Payload Bay Environment - IVE is open structure subject to facility environment. IVE provides payload heat exchanger as optional equipment for active thermal control of payloads.

f. Fill, Dump, Drain, Vent and Purge - IVE provides capability for pressure leak test to verify Interface fit. No fluid flow capability is planned for the IVE.

g. Remote Manipulator System (RMS) - IVE provides a stowed critical interference envelope. No active, movable RMS is planned for IVE.

The basic design of the IVE does not preclude augmentation to include the above design limitations with associated increase in cost.

2. Other constraints placed on the study to provide IVE operational flexibility and design commonality include:

   a. IVE support maximum payload of 65,000 pounds with safety factor of 4.

   b. IVE primary structure sized for worst case loading for entire payload bay (common size of structural members).

   c. Single primary structure design employed for both horizontal and vertical IVE configurations.

   d. No "off-limits" testing - IVE protects payload from exposure to voltages or signals which exceed the flight environment.

   e. Workstands are excluded from the IVE study IVE shall not preclude using Shuttle/Orbiter workstands (provide clean design lines for IVE).

4.0 HORIZONTAL IVE PRELIMINARY DESIGN CONCEPT

4.1 GENERAL DESCRIPTION

The basic IVE concept consists of two classes of equipment referred to as (1) standard IVE and (2) optional equipment. The standard IVE consists of the basic structure, operators console and those interface elements which are essentially used by the majority of payloads. Two exceptions are the inclusion of the provision for the preflight (T-4) umbilical panel and the X_O1307 bulkhead structure. The major elements of the standard IVE are shown in Figure 4-1. Optional equipment includes those payload interface elements that are unique to a specific payload or class of payloads as identified in Figure 4-2.

The primary criteria impacting the IVE design concept is given in Table 6.1. A key feature of the IVE design is its modularity which permits use of a portion of the IVE (single mid-body section, operators console, etc.) resulting in the inherent cost advantages associated with tailoring the configuration for specific user needs.

As defined in this study the IVE is a set of dimensionally accurate physical and functional hardware representative of the Orbiter payload accommodations. It provides the capability to verify Orbiter/payload I/F compatibility, support payload functional and performance checkout including mission simulation, and support development and verification of ground operations including crew training, procedures and payload handling GSE. Major emphasis was placed on the use of either off-the-shelf hardware or previously developed Orbiter related hardware to minimize engineering development and procurement costs.

4.2 HORIZONTAL IVE STRUCTURE AND MECHANISMS SUBSYSTEMS

The standard IVE structure consists of the primary structure (all major load carrying members in the mid-body supporting the payload), and the secondary structure (aft flight deck support stand, the X_O576 and X_O 1307 bulkheads, and brackets necessary to support the payload interface elements). The standard IVE mechanisms include the following payload interface elements: payload support attach fittings (longeron and keel), primary power interface, payload wire trays (right and left side), preflight umbilical (T-4) panel provision, RMS and door actuator critical interference envelopes, and adjustable floor jacks (leveling of IVE system assembly).

The primary structure utilizes design commonality to maximum advantage resulting in over all cost savings. Three mid-body sections identi-

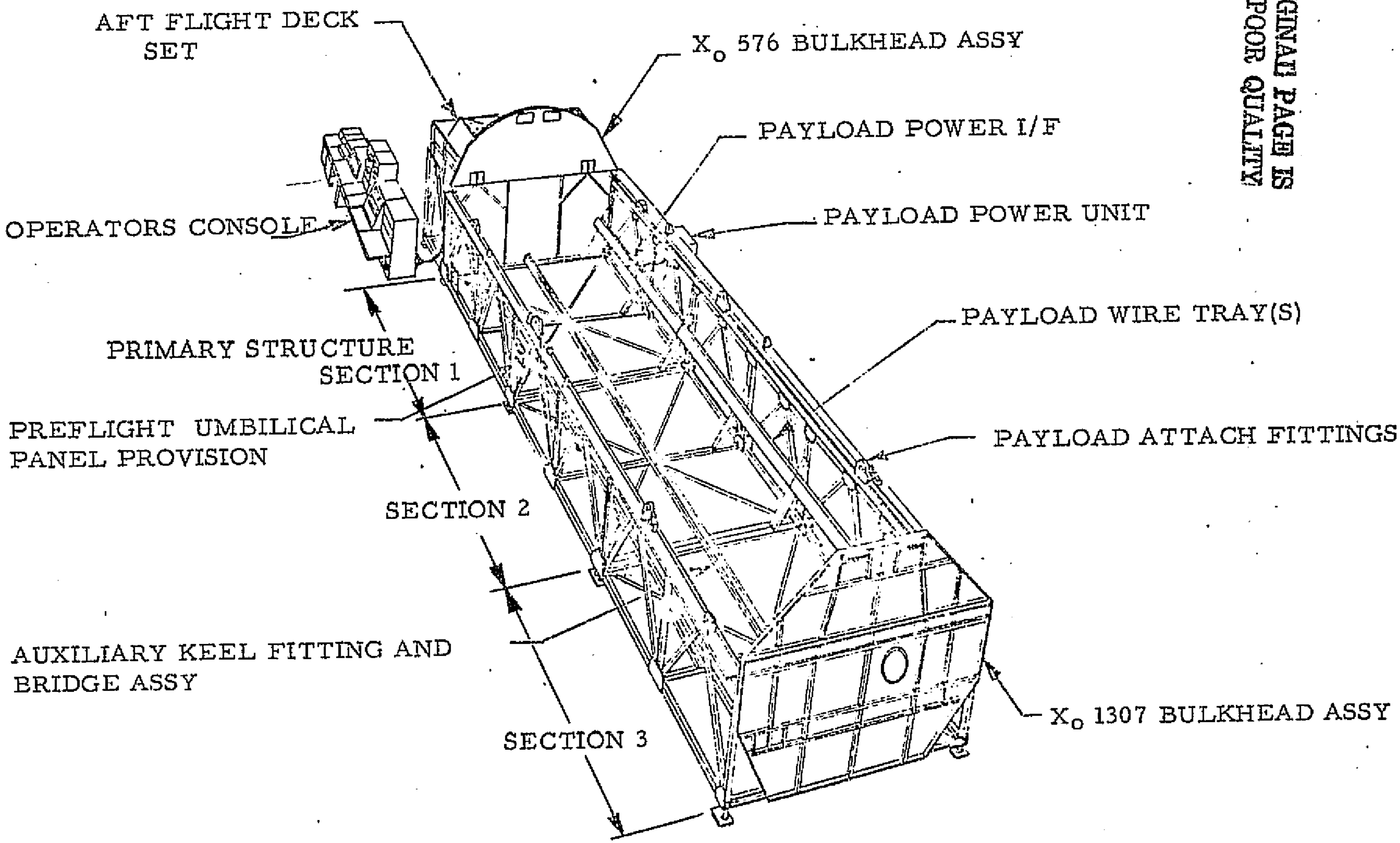

FIGURE 4-1 STANDARD HORIZONTAL IVE CONCEPT

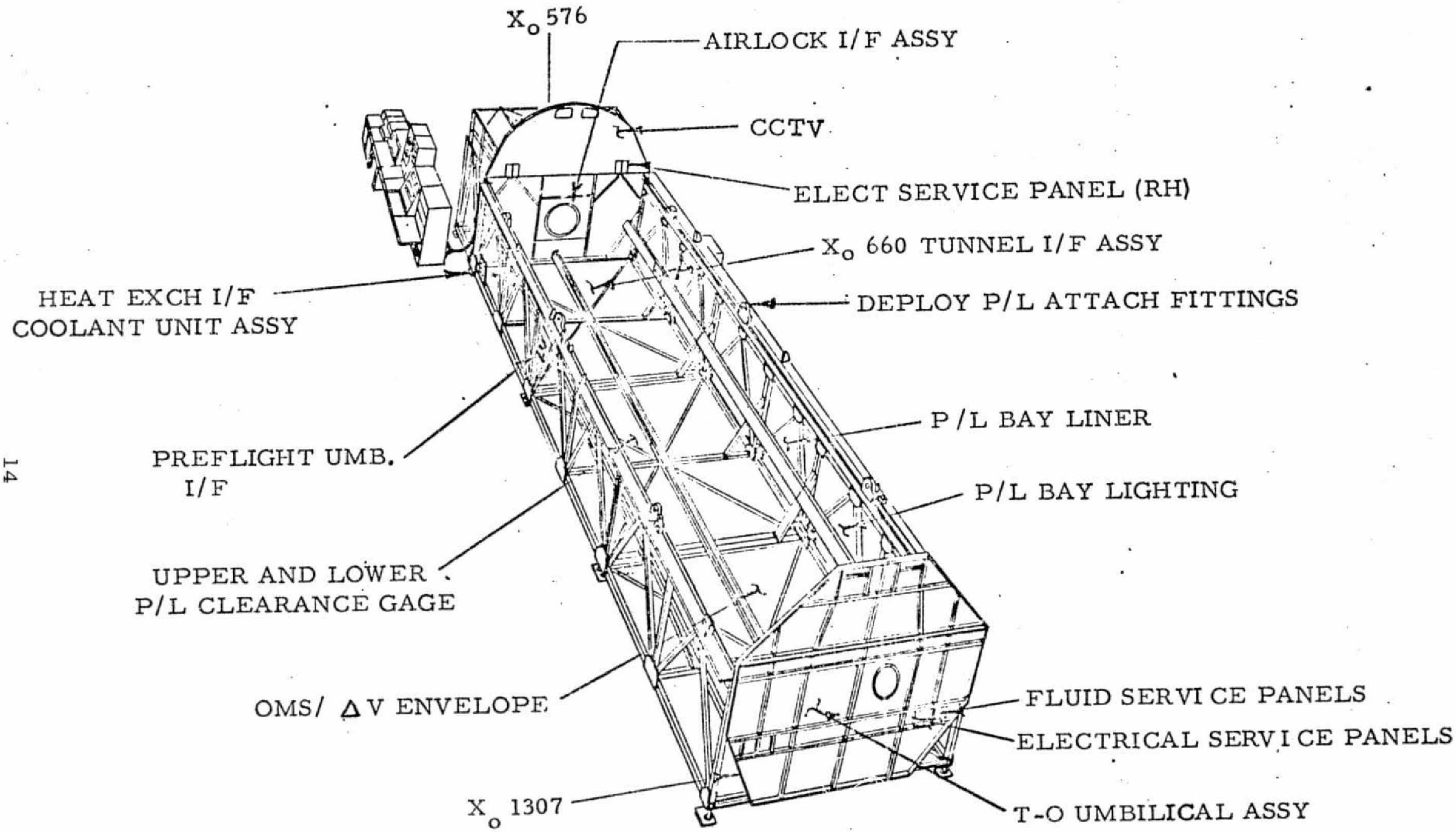

FIGURE 4-2 IVE OPTIONAL EQUIPMENT

cal in structural member design, make up the IVE mid-body (Figure 4-1). Each section is made-up of welded tubular ASTM 50v Grade B steel members (right hand and left hand truss assemblies) connected by I-beam and diagonal tie rods for squaring (Figure 4-3). Upon system assembly, the three mid-body sections are connected to each other to reflect the critical payload attach locations (predrilled in each section). Secondary structure for the installation of the standard IVE payload I/F elements and optional equipment is either welded (integral with primary structure) or bolted using holes predrilled in the primary structure. The combination of welded and bolted construction as shown in Figure 4-3 (cross beam and truss assembly) allows for compensation of design and manufacturing tolerances by locating and drilling the cross beams during section assembly using the noles in the truss assembly tab as a guide (See Figure 4-3). The primary structure was sized to meet the requirements for a maximum 65,000 pound payload using a common structure design for both horizontal and vertical IVE configurations.

The continuous longeron bridge design approach for payload attachment (Figure 4-3), enhances IVE operations requiring minimal effort to reconfigure from one payload to the next. A portion of the upper rail is removable at each end of the upper longeron so that addition/removal of payload attach fittings is facilitated. Relocation of upper longeron payload primary attach fittings is accomplished by removing the locking pins, sliding the fitting to a new location and inserting locking pins. The stablizing fittings slide freely on the rail to any desired location, the continuous keel beam design approach (Figure 4-3) facilitates locating the payload keel fitting to any desired available location.

A major concern impacting the IVE structural design is the operational support required to assemble, checkout and verify that the IVE is a valid configuration at the user site. IVE structural reassembly verification is achieved through the use of engineering tooling aids including optics, load alignment pins, and alignment markers integral with the structure, and a master alignment tool to verify that critical payload interfaces are within allowable design tolerances. The IVE structure and mechanisms were designed for minimum maintenance over long operational times (10-20 years). Periodic structural alignment verification is achieved by optically checking the alignment of the bridge rails and using the master alignment tool to verify the payload interface elements.

4.3 HORIZONTAL IVE ELECTRICAL SUBSYSTEM

The standard IVE electrical subsystem includes the operators console, the aft flight deck set, the DC power set, the cable set and software

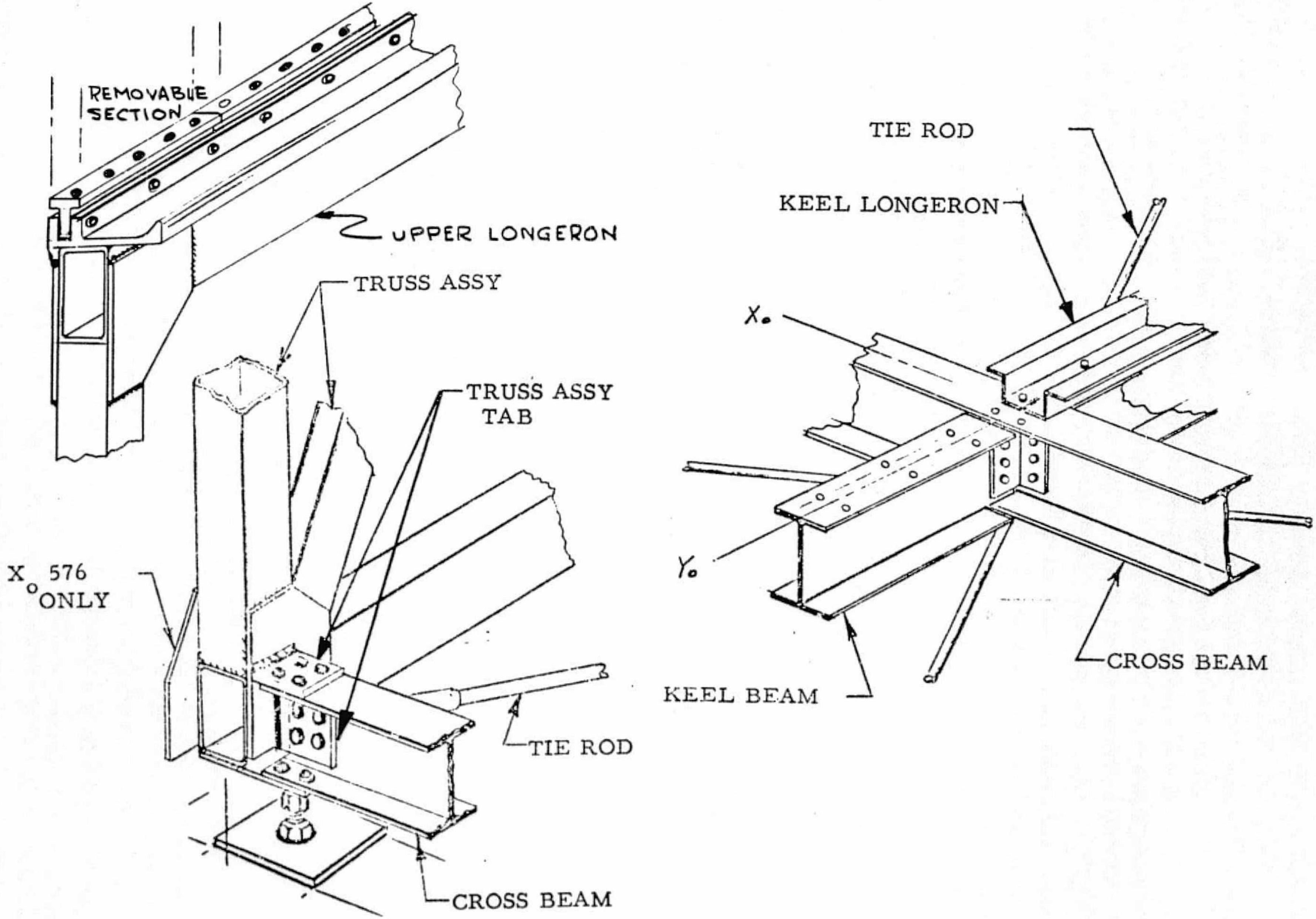

FIGURE 4-3 DETAILS OF IVE STRUCTURE DESIGN

(See Figure 4-4). Key design features include maximum use of commercial test equipment, modular design, "stand alone" (independent) operation (requires no facility support GSE), payload accessibility to payload GSE, IVE accepts control by and delivers data to the payload user site Data Processing Facility, and automated (with manual mode) operation.

Operational capabilities include Orbiter/Payload I/F verification (Pin/connector matching, resistance continuity and isolation checking), payload functional testing (1) verify Orbiter/payload performance and (3) simulate mission/on-orbit timelines and sequencing.

The electrical system is designed to stimulate the payload with digital commands, over the flight range of values, and receive responses from the payload subsystem. Design incorporates safeguards for preventing out-of-limit signals from being imposed on payload input circuits. Measurement instruments are provided to measure and record all signal characteristics. Data processing capability is provided with output formats compatible with the Orbiter comm and data handling system.

A DC power unit for the payload +28 vdc buses simulating Orbiter fuel cell performance in the 0 to one Hz range is provided.

Mechanization of the electrical system (Figure 4-5) is provided by a modular, analog and digital interface verification test system under supervision of a controller/central processor unit. Flexibility of operation is provided by an asynchronous data bus interfacing with commercial proven "off-the-shelf" test equipment and Space Division designed hardware.

Payload Integration functions not incorporated in the IVE design include: EMI/EMC testing, off-limit testing, RF checkout (payload interrogator with detached payload interface, and software validation.

4.3.1 Operators Console

The operators console simulates the payload related functions of the Orbiter Communication and Data Handling (C and DH) system and the Flight Computer Operating System (FCOS). Mechanization of the operator console is based on a modular, analog and digital interface verification test system under supervision of a controller central processor unit (C/CPU).

Flexibility of operation is provided by an asynchronous data bus interfacing with a mix of "off-the-shelf" test equipment and Rockwell International Space Division designed components. Key factors influencing the design of the electrical subsystem were cost, performance, opera-

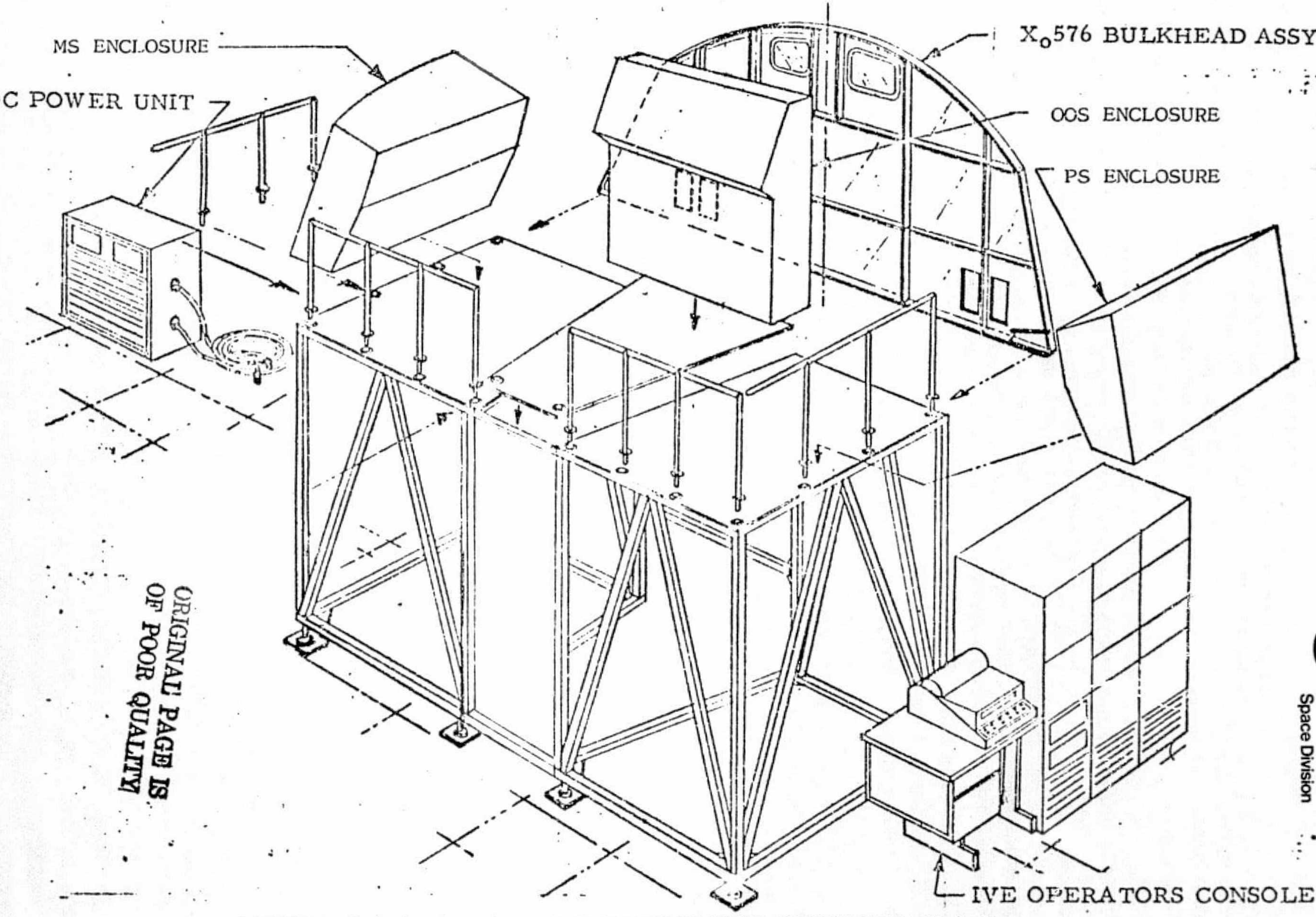

FIGURE 4-4 STANDARD IVE ELECTRICAL SUBSYSTEMS AND AFT FLIGHT DECK CONFIGURATION

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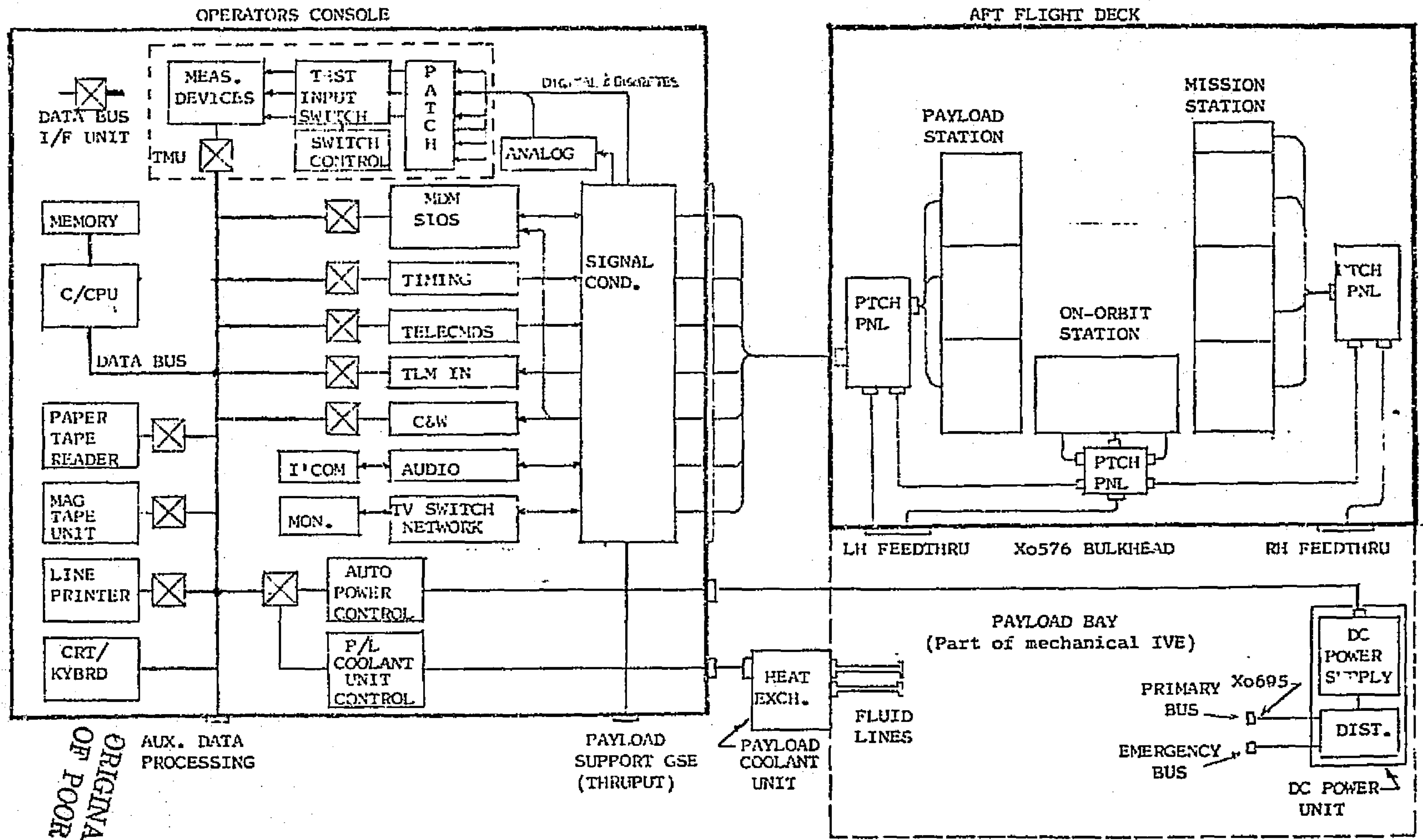

FIGURE 4-5 IVE ELECTRICAL SUBSYSTEMS FUNCTIONAL BLOCK DIAGRAM

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tional requirements, hardware modularity and software flexibility to accommodate a changing spectrum of data formats.

The console consists of an input/output unit containing a controller/central processor unit (C/CPU), 64k word memory, CRT/keyboard, high speed line printer, disc drive, magnetic tape drive, paper tape reader, card reader and tape search unit; A test measurement unit (TMU) containing remote programmable test equipment including a waveform analyzer, frequency counter, digital voltmeter and a wideband 28 channel tape recorder; An Avionics Interface Element (AIE) containing signal distribution modules, signal conversion modules, control panels (C&W, safing, video power) and data bus interface units. Figure 5 is a block diagram showing the interface between the signal conversion modules, C/CPU and the payload. Commands/data generated by the signal conversion modules (formatters, encoders) under control of system software are specified by (Volume 14) and simulate the analog, discrete and serial digital outputs of the Orbiter provided payload accommodations. Payload responses are accepted by the test measurement unit for signal analysis or by the signal conversion modules for real time processing by the C/CPU.

4.3.2 Aft Flight Deck Set (AFDS)

The Aft Flight Deck Set (Figure 4-4) simulates the Orbiter mission station (MS), on-orbit station (OOS), and payload station (PS) including all payload related control and display equipment. The AFDS consists of the X_o576 payload service panels, MS, PS, OOS electronic enclosures, payload related control and display equipment, patch panels and cabling. Cabling between the X_o576 bulkhead electrical service panels and the MS, OOS and PS will be an exact physical and functional simulation of the Orbiter installation. Payload related control and display equipment is included for the following functions: (1) standard IVE - CRT/keyboard and DEU, power, caution and warning, mission timer, and audio, (2) optional equipment - CCTV, and lighting.

4.3.3 DC Power Set

The DC power set provides nominal 28 vdc power at 400 amps with variable voltage capability simulating the Orbiter payload fuel cell power interface. The DC power set consists of a commercial DC power supply, power switching assembly and distribution module. Transient characteristics of the Orbiter fuel cell in the 0 to 1 Hz region are simulated by sensing the load changes, comparing the load changes to algorithms approximating the load line curves of the fuel cell (in C/CPU). A resistance output signal is generated by the C/CPU and is used to control the DC power supply voltage regulator.

4.3.4 IVE Software

The standard IVE electrical subsystems include software and programming aids as shown in Figure 4-6. The System Support Software provides control of all IVE peripherals, special purpose interface handlers (formatters, decoders, etc). The Test Application Software consists of a library of subroutines for performing specific payload-subsystem functions (software building blocks to be integrated into the System Test Program software by the user). Since an Orbiter General Purpose Computer is not used for the IVE CPU the IVE does not have the capability to verify payload flight software. The IVE does, however, provide capability to support development and test of payload flight software and check sizing timing and cycling.

4.4 HORIZONTAL IVE FLUID SUBSYSTEMS

The IVE fluid subsystems, categorized as optional equipment, include (1) the payload heat exchanger and related controls, displays, interface panel, fluid lines and purge and test, (2) X_o1307 fluid interfaces (3) propellant dump line interfaces, (4) ground and flight RTG coolant interfaces and a pressure leak detection unit.

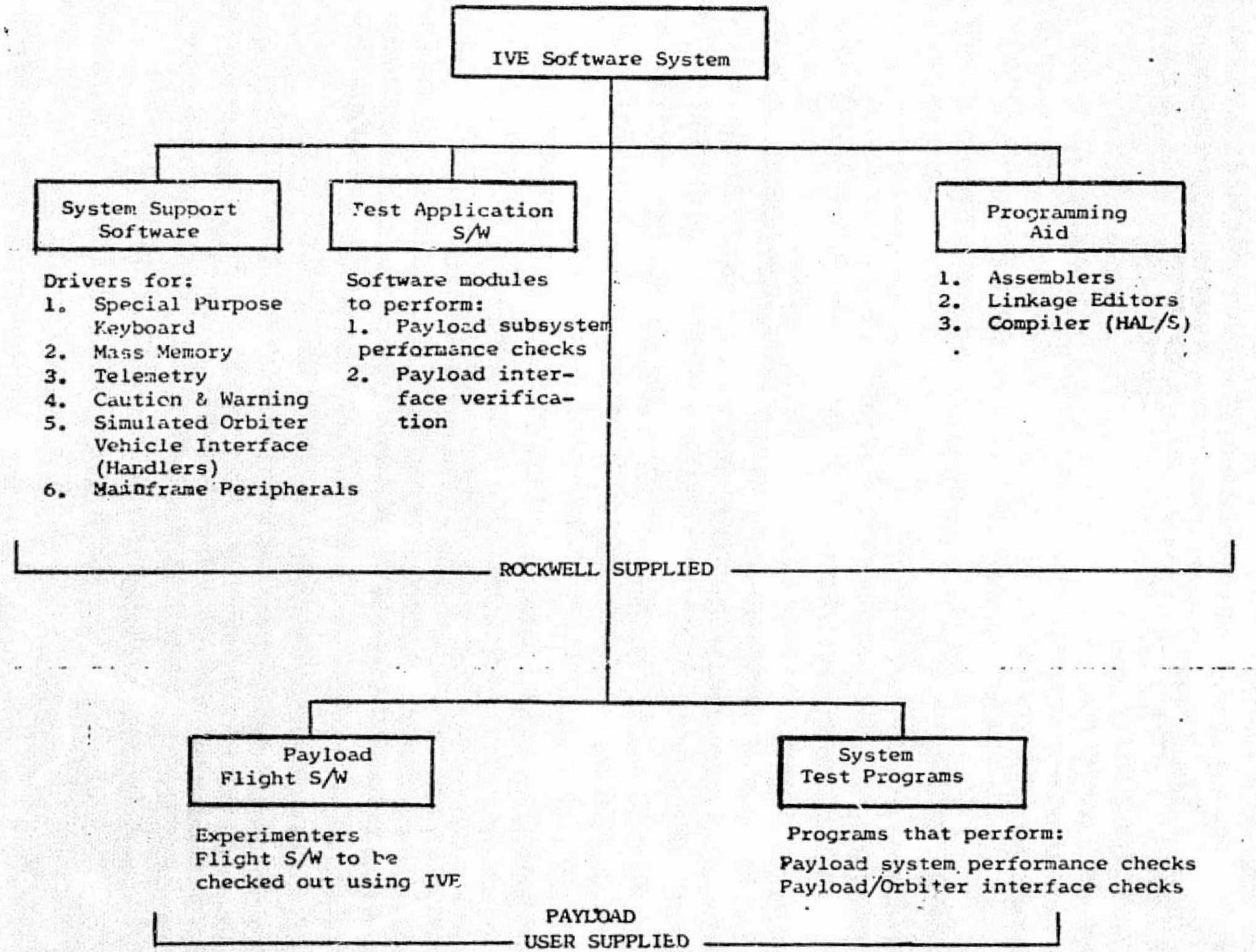

FIGURE 4-6 IVE SOFTWARE SYSTEM DEFINITION

5.0 VERTICAL IVE CONCEPT

5.1 VERTICAL IVE CONCEPT OPTIONS

A vertical IVE concept was developed using the Horizontal IVE as a point of departure to define design and cost deltas. Three concept options were defined by NASA-KSC for investigation:

OPTION I	IVE Electrical, Fluid Subsystems and MS, PS, OOS Elements Located at Floor Level
OPTION II	IVE Operators Console, Power Supply and Coolant Unit Located at Floor Level
OPTION III	All IVE Elements Located on Vertical Stack - Location At/Near X_o576

5.2 DESIGN CONSTRAINTS

The major design constraints imposed by NASA-KSC were (1) "stand alone" structure - I/F with SAEF-1 building structure, (2) payload will be installed/removed using an overhead crane, (3) IVE compatible with 100K clean room, (4) vertical IVE will not preclude use in horizontal position, and (5) access and workstands other than X_o576 are not part of the vertical IVE.

In addition to the performance requirements imposed on the horizontal IVE, use of the vertical IVE to support (1) critical access verfication with the payload installed in the IVE and (2) payload ground operational procedure development and verification with respect to the Orbiter was considered and delta design impacts to the horizontal IVE were defined.

5.3 VERTICAL IVE DESIGN CONCEPT

An initial analysis was performed with results summarized in Table 5.1 identifying for the three options delta performance requirements to the horizontal IVE. Based on these results, NASA-KSC selected Option III for further analysis.

Major design deltas to the horizontal IVE consisted of relocating IVE equipment (operators console, coolant unit, power supply), redesigning the aft flight deck, addition of an X_o576 work platform,

TABLE 5.1 VERTICAL IVE CONCEPT COMPARISON SUMMARY

IVE SUBSYSTEM	OPTION I	OPTION II	OPTION III*
PRIMARY STRUCTURE			BEEF-UP TO SUPPORT 19K LB PERSONNEL, IVE EQUIP & STRUCT
OPERATORS CONSOLE	SIGNAL CONDITIONING AND REMOTE MONITORING REQD: HIGHER IMPEDANCE, NOISE, CROSSTALK, SIGNAL ATTENUATION	SAME AS OPTION I	NO IMPACT
DC POWER UNIT	POWER CONDITIONING, REMOTE SENSING REQD: HIGHER SOURCE IMPEDANCE, RIPPLE VOLTAGE LEVELS, VOLTAGE DROPS, POOR TRANSIENT RESPONSE	SAME AS OPTION I	NO IMPACT
PAYLOAD COOLANT UNIT	LARGER PUMP, REMOTE T, F, P SENSING, LINE SIZE AND INSULATION REQD:	SAME AS OPTION I	NO IMPACT

* OPTION III SELECTED BY NASA-JSC FOR FURTHER DEVELOPMENT

redesign of the X_o576 and X_o1307 bulkheads, and the addition of a support stand (at base of IVE). A common primary structure design was used for both the horizontal and vertical IVE which reflects the design impacts of the vertical IVE Option III (beef up of structural member sizing and wall thickness to meet column buckling and structural stability requirements (displacement under load).

The X_o576 work platform, IVE equipment and the simulated Orbiter aft flight deck configurations for the vertical IVE are shown in Figure 5-1. A major redesign of the X_o576 bulkhead and aft crew compartment is required to (1) allow swinging it out of the way during payload installation and removal using the overhead crane, (2) support increased loads experienced by the X_o576 bulkhead in the vertical position, and (3) simulate the Orbiter interior crew cabin mold-line and access hatch/passageways.

Of interest to NASA-KSC was the capability of the IVE to be used in a split stack configuration as shown in Figure 5-2 and what resultant design impact would be incurred by the IVE. The modular design approach utilized for the IVE allows use of either 1, 2 or 3 mid-body sections (each 20 feet long) with the X_o576 work area in a vertical stack configuration since the primary structure was designed for the maximum load condition using common member sizing throughout the mid-body. Additional base support stand(s) would be required. Dependent upon the specific usage, interconnecting payload and IVE cabling between the split stacks would require structural support.

Interfaces between the IVE and the SAEF 1 facility at KSC include floor mounting pads (see Figure 5-2) for typical location, electrical power, facility lighting, payload cooling water supply and drain, and gaseous nitrogen for purging coolant lines.

The structural design deltas incurred by the horizontal IVE for vertical operation are summarized in Table 5.2. No significant changes are required in the IVE electrical subsystems with the exception of new interconnecting cable assemblies between the operators console, power supply, coolant unit and the IVE aft flight deck. Rerouting of the fluid lines between the payload coolant unit and the IVE coolant interface is also required.

Delta costs to the horizontal IVE will be incurred for design and development of the aft flight deck and crew compartment simulation, X_o576 work platform and base support stands with associated increased materials costs.

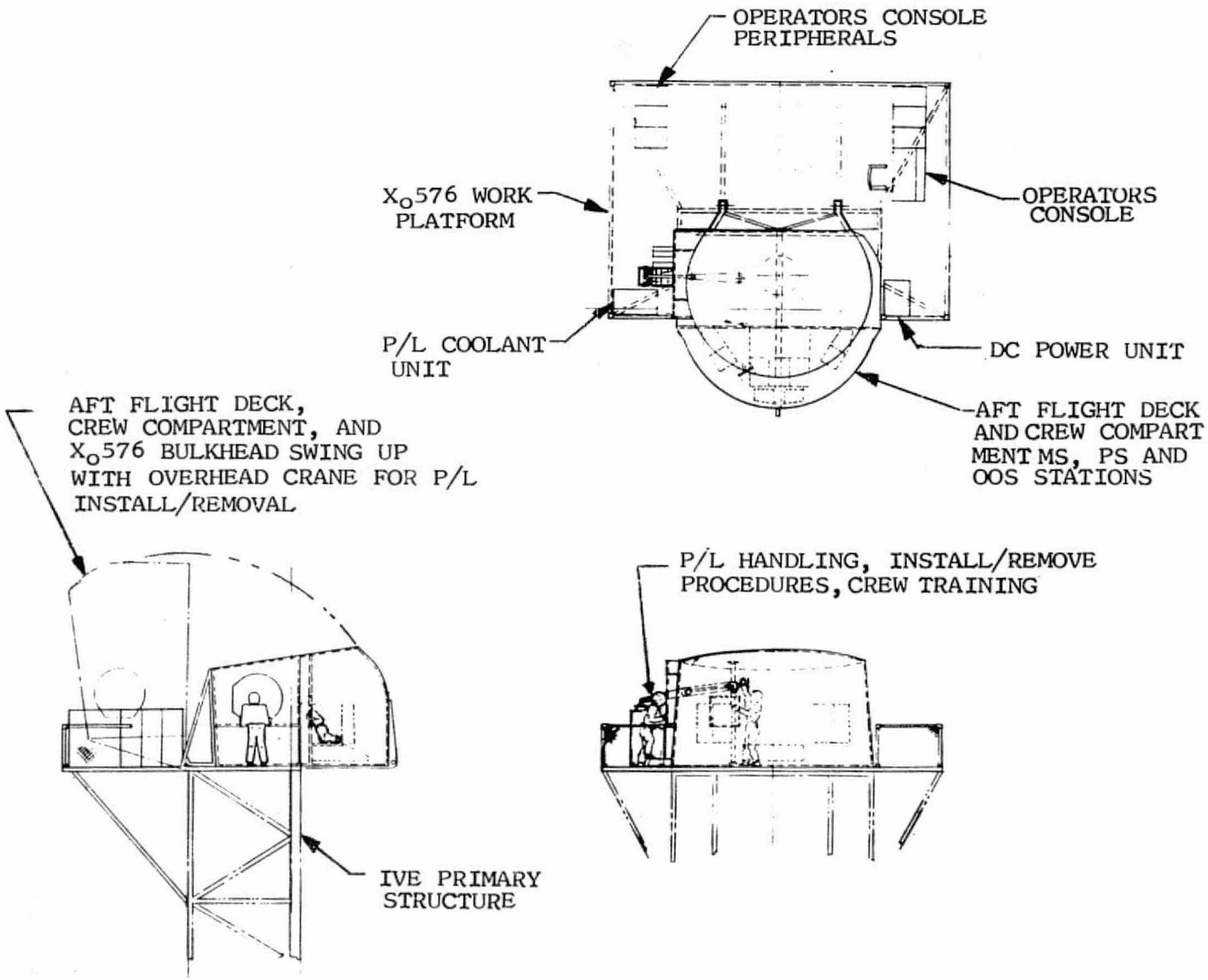

FIGURE 5-1 VERTICAL IVE X_o576 WORK AREA CONFIGURATION

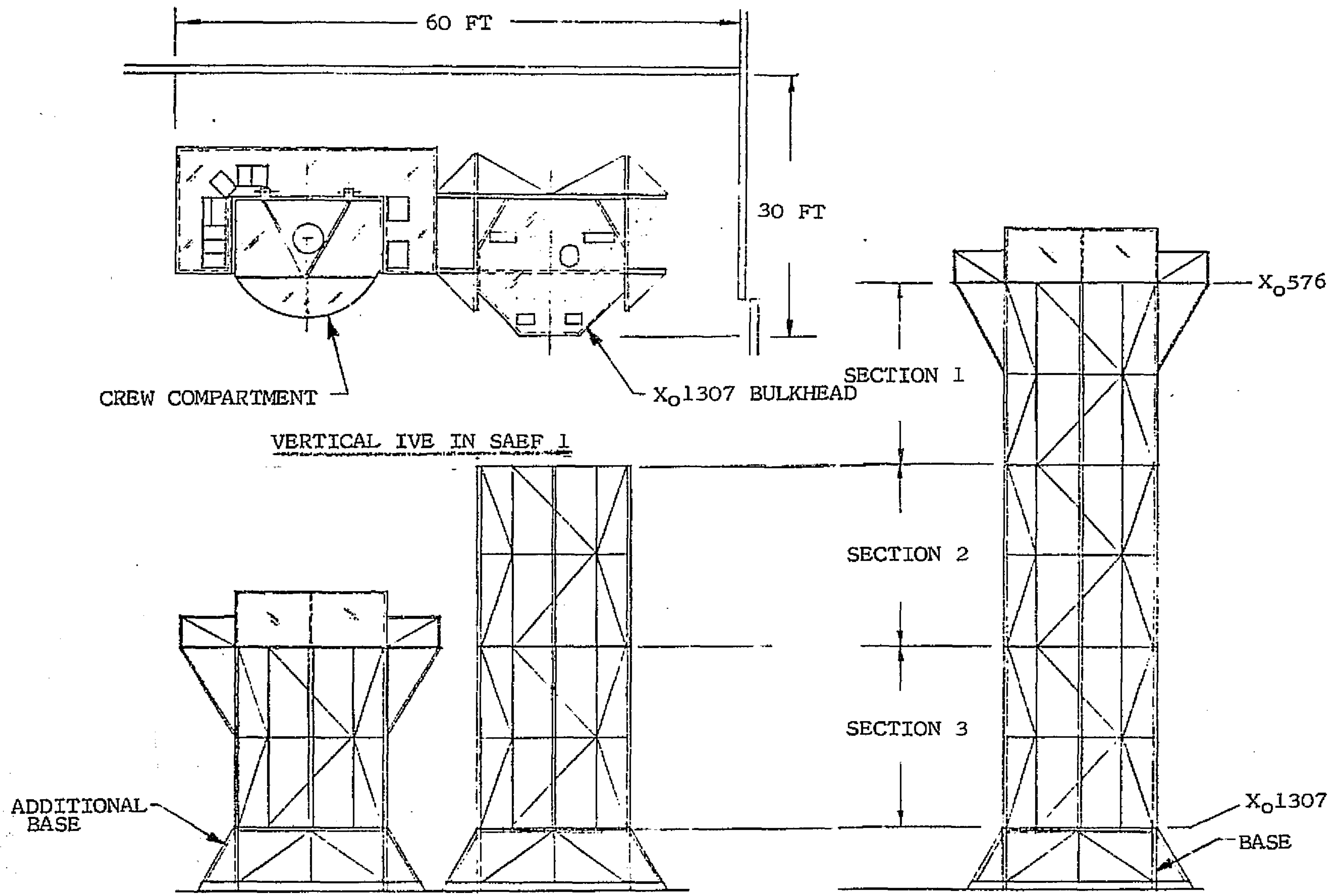

FIGURE 5-? VERTICAL IVE SPLIT STACK CONFIGURATION

TABLE 5.2 HORIZONTAL IVE DELTA DESIGN FOR VERTICAL OPERATION

STRUCTURE ELEMENT(S)	DESIGN DELTAS
LONGERON VERTICAL POST DIAGONAL POST LOWER CHORD	INCREASE WIDTH FROM 4 TO 6 INCHES
LOWER CHORD	INCREASE WALL THICKNESS 1/4 TO 3/8 INCHES
STIFFENER (LONG)	REPLACE ANGLE CLIP WITH INTEGRAL STRUCTURE STIFFENER MADE FROM BULB ANGLE 0.5 INCH THICK
CROSS BEAM	INCREASE DEPTH FROM 6 TO 10 INCHES
SECTION PLATES, BOLTING	INCREASE PLATE THICKNESS, BOLT SIZE AND PATTERN
X_o 1307 BULKHEAD ASSEMBLY	INCREASE PLATE THICKNESS (0.06 TO 0.125 IN) AND FRAME MEMBER WALL THICKNESS (0.125 TO 0.25 IN)
AFT CREW STATION X_o 576 BULKHEAD	REDESIGN: USE MS, PS, OOS SECONDARY STRUCTURE AND X_o576 BULKHEAD INTERFACES
SUPPORT STAND	ADD: NEW DESIGN

6.0 IVE DESIGN TRADE STUDIES

Design concept trade studies were performed to determine the preferred design approach for the IVE primary structure, payload support and attachment, and electrical subsystem. The trade studies were governed by the evaluation criteria listed in Table 6.1.

TABLE 6.1 IVE DESIGN EVALUATION CRITERIA

- Performance
- Simplicity
- Modularity
- Hardware Availability
- Commonality
- Operational Flexibility
- Common Structure Design for Horizontal and Vertical IVE Operation
- Ease of Addition/Removal of Payload I/F Optional Equipment
- Manufacturing Complexity/ Tooling
- Transportability
- Ease of In-Field Assembly
- Configuration Control
- Comparative Cost
- Facility Support

6.1 STRUCTURAL DESIGN TRADES

The initial IVE structural design was greatly influenced by Spacelab requirements including horizontal operation only, air transport to meet a tight delivery schedule for delivery to ERNO, multiple assembly/ disassemble for use at various geographic locations and storage. These considerations resulted in a modular mid-body consisting of four sections each ~15 feet long. Prior to the start of the horizontal IVE preliminary design effort, the requirement for air transportability was relaxed allowing section assemblies with lengths in excess of 20 feet resulting in the development of a 3 section mid-body. Three panel and four panel Pratt and modified Warren truss configurations (Figure 6-1) were evaluated leading to the selection of the modified Warren Truss as the preferred structural design approach. Two mid-body section design concepts were investigated (Figure 6-1) with concept B selected based on loading considerations, structural sizing, design simplicity, ease of manufacturing, minimal tooling requirement, and applicability for compensating for design and manufacturing tolerances during each section assembly and section to section system assembly.

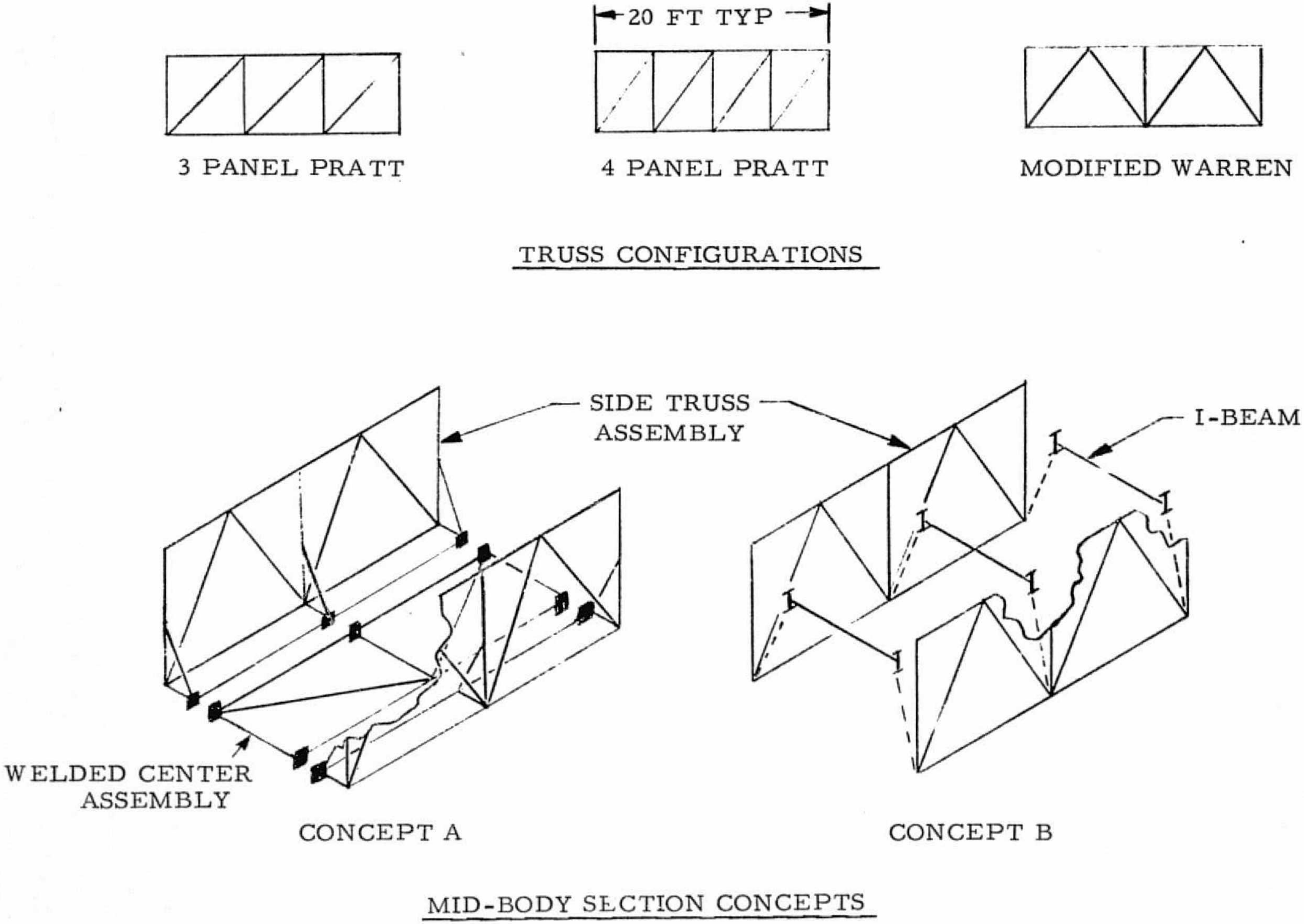

FIGURE 6-1 IVE STRUCTURAL DESIGN TRADES

The IVE baseline design concept for payload attachment at the start of this study envisioned a short bridge with three positions available for the payload attach fitting. This design required removing and installing the bolted on IVE bridge from one payload to the next. After setting up for eleven payloads, operational set up costs associated with the payload attach fitting exceed the initial delta cost to provide a continuous simulated bridge the entire length of the mid-body. The longeron bridge concepts considered are shown in Figure 6-2. The bolted clevis design concept was selected based on a comparison as shown in Table 6.2.

6.2 ELECTRICAL SUBSYSTEM DESIGN TRADES

Two design concept options were investigated in the development of the IVE electrical subsystem:

OPTION I - Emphasis on use of Shuttle Orbiter design non-flight qualifiable hardware augmented with commercial test equipment.

OPTION II - Use of commercial test equipment using a minimum of Shuttle Orbiter design hardware augmented with hardware designed and developed by Space Division in support of the Orbiter development.

Table 6.3 summarizes the concept comparison showing advantages of design Option II over Option I leading to the selection of Option II for further design definition. As indicated, use of Option I requires equipment modifications to provide signal variation and self-test, troubleshooting and maintenance. This negates the sought for advantages of using Orbiter design equipment with respect to savings in design engineering, configuration management, and maintenance and operations. Also supporting the selection of Option II are the high initial hardware costs of Option I (see example in Table 6.3) compared to Option II. In addition, configuration management costs may be substantially lower for Option II than for Option I as performance may be varied for Option II mainly by procedural, front panel switching and software changes.

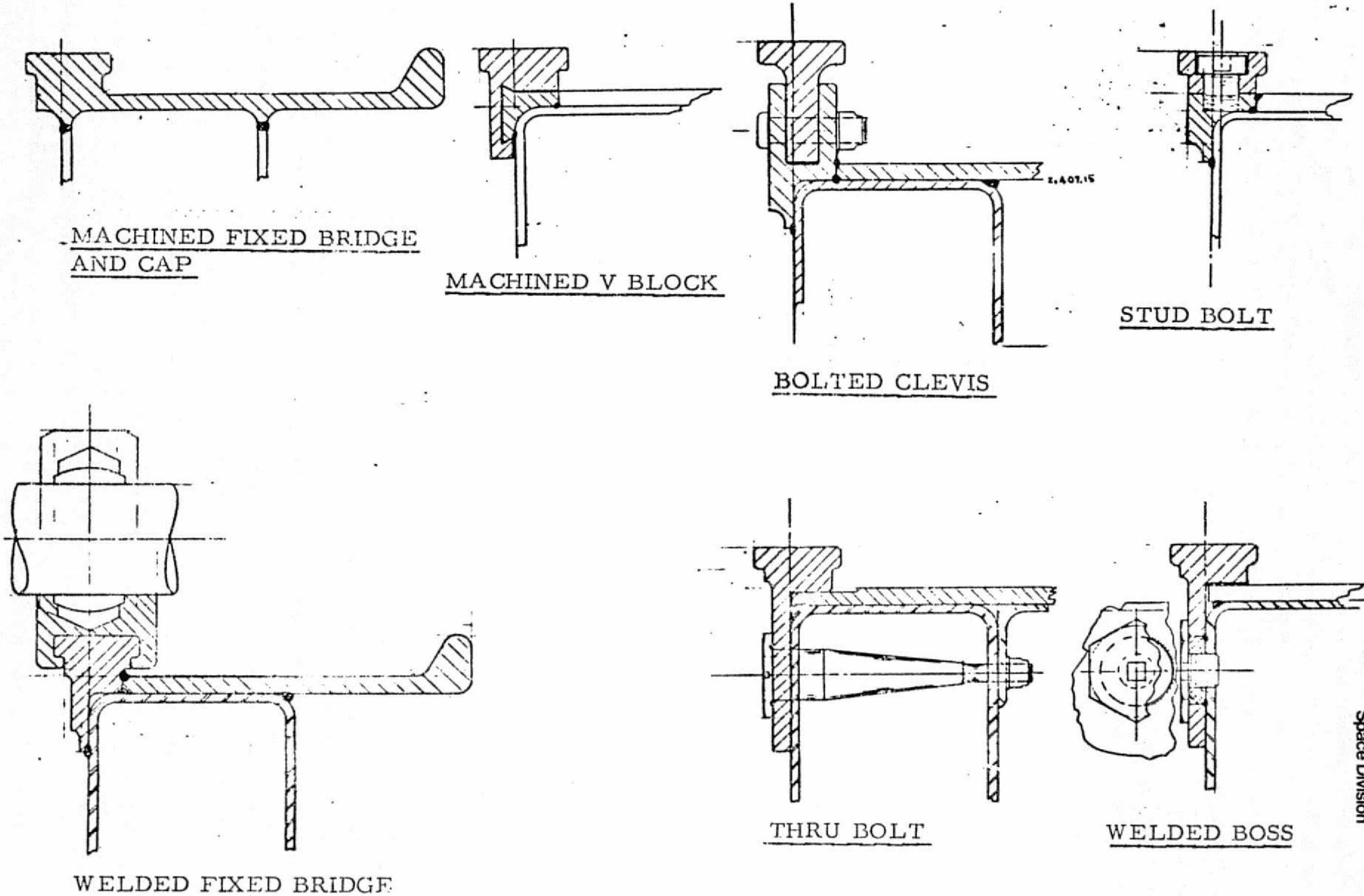

FIGURE 6-2 PAYLOAD LONGERON BRIDGE CONCEPTS

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TABLE 6.2 PAYLOAD LONGERON BRIDGE CONCEPTS COMPARISON

BRIDGE DESIGN CONCEPT	REMOVABLE BRIDGE	LONGERON WALL BEARING	BOLTING REQMT'S	MACHINING COMPLEXITY	MACHINED SURFACE AREA	WELDING COMPLEXITY	WELDING (INCHES OF)	MAINTAINABILITY
SPACELAB BASELINE	YES	$\boxed{\text{YES}}$	$\boxed{\text{HIGH}}$	LOW	HIGH	N/A	N/A	MED
MACHINED FIXED BRIDGE & CAP	$\boxed{\text{NO}}$	N/A	N/A	HIGH	LARGE	HIGH	LOW	$\boxed{\text{POOR}}$
WELDED FIXED BRIDGE	$\boxed{\text{NO}}$	N/A	N/A	LOW	MED	LOW	HIGH	$\boxed{\text{POOR}}$
MACHINED V BLOCK	YES	N/A	N/A	$\boxed{\text{HIGH}}$	LARGE	LOW	MED	$\boxed{\text{POOR}}$
BOLTED CLEVIS *	YES	N/A	MED	LOW	LARGE	LOW	HIGH	GOOD
THRU BOLT	YES	$\boxed{\text{YES}}$	$\boxed{\text{HIGH}}$	LOW	MED	N/A	LOW	MED
STUD BOLT	YES	N/A	MED	$\boxed{\text{HIGH}}$	$\boxed{\text{LARGE}}$	LOW	MED	$\boxed{\text{POOR}}$
WELDED BOSS	YES	N/A	$\boxed{\text{HIGH}}$	$\boxed{\text{HIGH}}$	LARGE	MED	MED	$\boxed{\text{POOR}}$

$\boxed{}$ IDENTIFIES BASIS FOR CONCEPT REJECTION

* HORIZONTAL IVE SELECTED CONCEPT

TABLE 6.3 IVE ELECTRICAL SUBSYSTEM CONCEPTS COMPARISON

REQUIREMENT EVALUATION PARAMETER	OPTION I		OPTION II	
• INTERFACE SIGNAL VARIATION OVER FLT RANGE	REQ EQUIP MODIFICATION		COMMERCIAL TEST EQUIP CAPABILITY	
• OPERATIONAL FLEXIBILITY	HDWRE REDESIGN OR REPLACEMENT, DOES NOT PROVIDE ACCESS FOR TROUBLESHOOTING AND MAINTENANCE TYPICAL OF TEST EQUIP		MODULAR DESIGN WITH ASYN-CHRONOUS DATA BUS, ACCOMMO-DATE SIGNAL INTERFACE CHANGES THROUGH SOFTWARE/ EXISTING HARDWARE	
• SELF-CHECK	REQ ADDITIONAL EQUIP TO CHECK EACH INTERFACE		BUILT IN COMMERCIAL TEST EQUIPMENT	
• HARDWARE AVAILABILITY	DEPENDENT ON SHUTTLE, SPACELAB IVE SCHEDULE CONFLICT		DEPENDENT ON DESIGN SPEC RELEASE, NOT DEPENDENT ON ORBITER HARDWARE DELIVERY SCHEDULE	
• CONFIGURATION CONTROL	DELTA PLAN REQD		DELTA PLAN REQD	
• COST (UNIT RECURRING)				
EXAMPLE:				
COMPUTER	GENERAL PURPOSE COMPUTER (GPC)	360K	MINI	40K
AUDIO	AUDIO CENTRAL CONTROL UNIT	120K	SIG. COND, HDSET SWITCH	7K

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7.0 SHUTTLE/PAYLOAD INTEGRATION ANALYSIS

7.1 OBJECTIVE

The primary objective of this Shuttle/payload integration analysis is to identify potential applications for the IVE to support payload integration through its development stage up to launch. The Space Transportation System (STS) introduces a new concept in which the propulsive stage (Shuttle) not only delivers and returns payload(s) to and from orbit but also may provide major support to the payload with respect to power, thermal control, commands, housekeeping data, payload data transfer, etc. during combined Shuttle/payload operations. As a result of the Shuttle supporting payload operations, the payload requires knowledge concerning the Shuttle Orbiter payload accommodations at earlier stages of payload development prior to the physical and functional bringing together (mating and checkout of the payload installed in the Orbiter).

This analysis is an initial investigation representing an objective analysis by the Space Division of Rockwell International of payload development data provided by the NASA to (1) develop at a top level, payload integration flow processes representing the general class of payloads, (2) determine the degree of Orbiter interface (I/F) knowledge required by the payload during the total payload integration process, and (3) identify potential applications of the IVE in support of the payload integration process to satisfy requirements as defined in (2) above.

A secondary objective was to develop evaluation criteria to support Shuttle Orbiter/payload integration trade studies. Space Division was specifically excluded by the NASA from conducting payload integration trade studies as a part of this analysis (see boxed in NASA responsibility in Figure 7-1).

7.2 ANALYSIS

The analysis was conducted as shown in Figure 7-1. The NASA provided payload integration data base was constrained by the Space Shuttle Payload Interface Verification document. An analysis of the data base resulted in the selection of the following five payloads as being representative of the general payload class: Solar Maximum Mission (SMM), Module with Pallet (Spacelab), Pallet Only (Solar Physics), Large Space Telescope (LST), and IUS/Mariner Jupiter Orbiter (IUS/MJO).

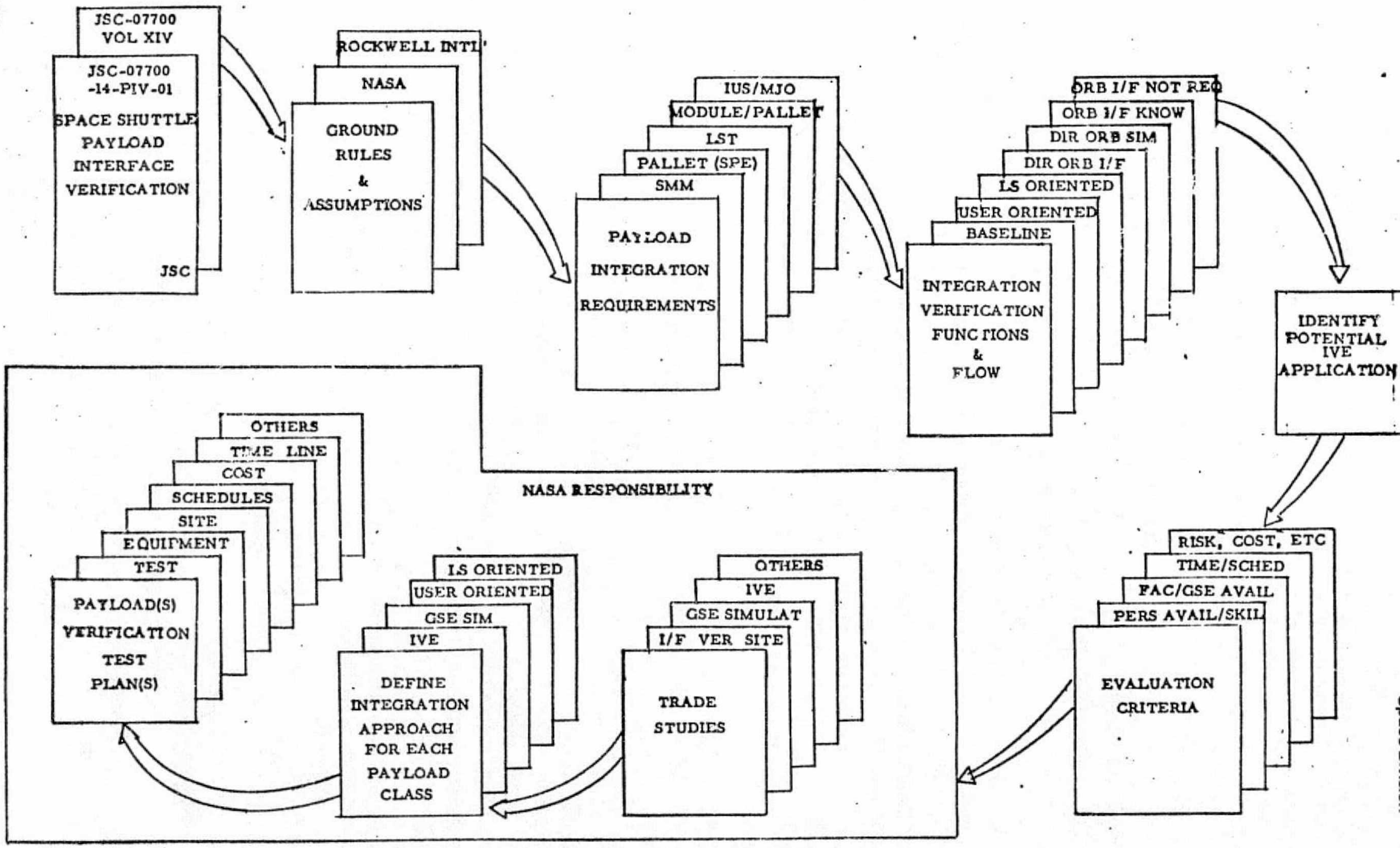

FIGURE 7-1 SHUTTLE/PAYLOAD INTEGRATION ANALYSIS STUDY LOGIC

The payload integration functional flow block diagrams (FFBD) based on an objective analysis of the payload user data provided by the NASA are identified as the baseline. Two payload integration flow options were also developed, (1) user site oriented-maximum integration functions accomplished prior to delivery to the launch site and (2) launch site oriented-minimum integration functions accomplished prior to delivery to the launch site.

Figure 7-2 shows a portion of the SMM payload integration functional flow block diagram illustrating the scope and degree of definition of payload integration functions accomplished in this analysis.

Four degrees of Orbiter interface knowledge were defined as follows:

1. No Orbiter I/F knowledge required.
2. Orbiter I/F knowledge required - data as defined in the JSC 07700 - Volume XIV Payload Accommodation Document.
3. Direct Orbiter Simulation required - actual physical simulation of an I/F, physical and/or functional (mechanical form, fit and electrical function - power and signals).
4. Direct Orbiter I/F - require payload installation into a flight Orbiter (Level I integration and preflight preparation and checkout).

Each of the functional blocks identified in the FFBD's (Figure 7-2) are number coded to reflect the above degrees of Orbiter I/F knowledge.

The optional payload integration processes (user site oriented and launch site oriented) showing deltas to the baseline FFBD's are defined in tabular form as illustrated in Table 7.1. The first column block numbers identify the specific block in the FFBD. The description column identifies the hardware involved, functions performed and operation level (subsystem and system payload makeup and cargo). The baseline location column by definition (from NASA data base) is either at the user site (payload contractor and/or Agency) or launch site. The X's in the Option I User Oriented column identify the FFBD functional blocks applicable to user site operation. X's in the Option II Launch Site Oriented column identify the FFBD functional blocks which are applicable at the launch site. Payload and Orbiter GSE simulation equipment requirement identification and potential IVE application are indicated by X's in the two checkout/test equipment columns. The special facility column indicates requirement for thermal vacuum, vibration, acoustics, EMI/EMC, etc. facilities required to perform a specific payload function. The

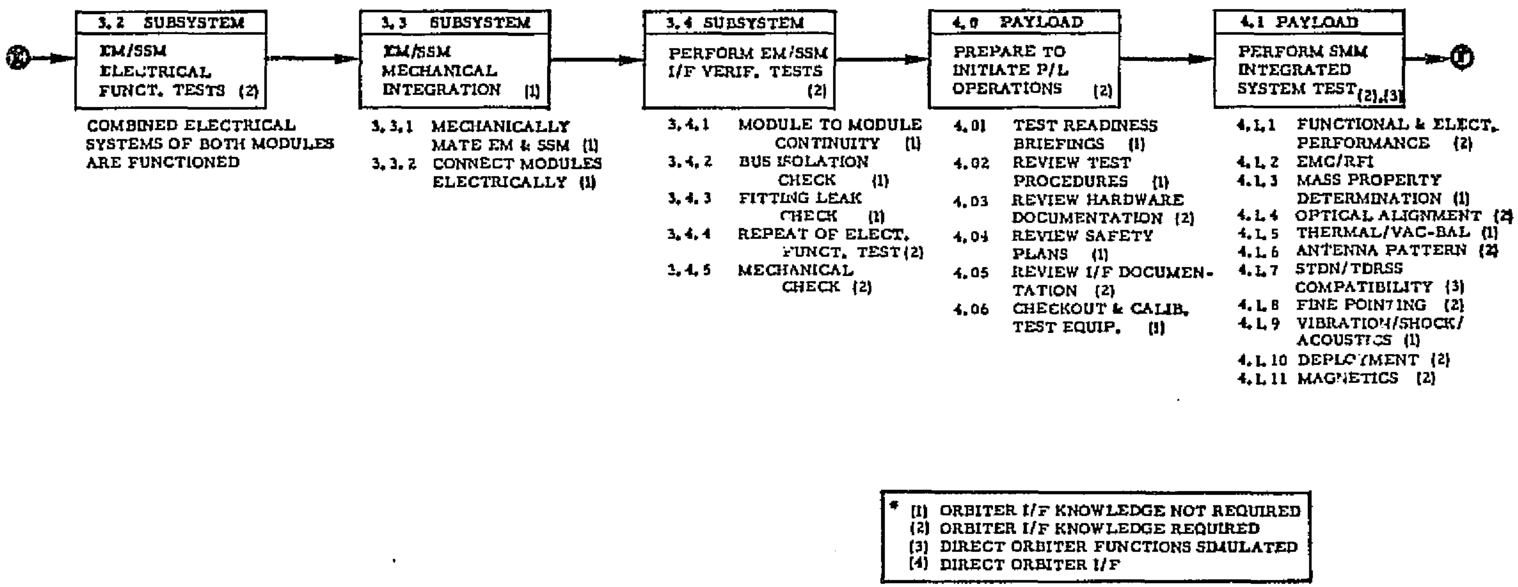

FIGURE 7-2 EXAMPLE - SOLAR MAXIMUM MISSION (SMM) FUNCTIONAL FLOW BLOCK DIAGRAM

TABLE 7.1 EXAMPLE - SOLAR MAXIMUM MISSION (SMM) INTEGRATION AND CHECKOUT MATRIX

BLOCK NO.	DESCRIPTION	INTERFACES				CHECKOUT/TEST EQUIPMENT		SPECIAL FACILITY	REMARKS
		* I/F KNOWLEDGE	BASELINE LOCATION	OPTION 1 USER ORIENTED	OPTION 2 LAUNCH SITE ORIENTED	GSE SIM.	IVE		
4.0	Prepare to initiate payload operations	(2)	User	X	X				
4.01	Test readiness briefings	(1)		X	X				
4.02	Review test procedures	(1)		X	X				Both sites
4.03	Review hardware documentation	(2)		X	X				
4.04	Review safety plans	(1)		X	X				
4.05	Review interface documentation	(2)		X	X				
4.06	Checkout & calibrate test equipment	(1)		X	X	X	X		
4.1	Perform SMM integrated system tests	(1), (2), (3)		X	X	X	X		
4.1.1	Functional & electrical performance	(2)		X	X	X	X		
4.1.2	EMC/RFI tests	(2)		X	X				Monitor EMI/RFI during funct. tests
4.1.3	Mass property determination	(1)		X				X	Special facility
4.1.4	Optical alignement	(2)		X	X	X	X		Both sites
4.1.5	Thermal/vac balance	(1)		X		X		X	Special facility required
4.1.6	Antenna pattern	(2)		X	X	X	X		Both sites
4.1.7	STDN/TDRSS compatibility	(3)		X	X				Direct link communications
4.1.8	Fine pointing	(2)		X	X	X	X		Both sites
4.1.9	Vibration/shock/acoustics	(1)		X	X	X		X	Special facility required
4.1.10	Deployment	(2)		X	X	X	X		
4.1.11	Magnetics	(2)		X		X			

* (1) ORBITER I/F NOT REQUIRED
(2) ORBITER I/F KNOWLEDGE REQUIRED
(3) DIRECT ORBITER FUNCTIONS SIMULATED
(4) DIRECT ORBITER I/F

remarks column provides clarification comments, identifies functions that may be performed at either User or Launch Site or required at both sites and identifies functions requiring additional trade studies to determine the preferred site to perform a specific function.

7.3 TRADE STUDY EVALUATION CRITERIA

In the final analysis, implementation of trade study results is governed by economic and social-political considerations. The evaluation criteria developed by Space Division considered only those factors contributing to the ultimate determination of $ cost. Table 7.2 shows the cost contributing categories and the associated criteria which must be converted to quantifiable values with an associated risk factor (confidence level) in order to perform meaningful payload integration trade studies. As indicated, the $ column must also be tempered by the absolute schedule time impact. For some payloads and integration functions schedule time is absolute and dictates the cost. For other payloads and integration functions time may be traded against cost. Associated with the time and $ is the risk factor (R column in Table 7.2). Development of submatrices applying $, T, and R against each function identified in the FFBD's and subsequent summation is required to arrive at an optional integration flow on a single payload basis. The data may then be used to support relative merits of non-optional payload integrating flow for one or more payload classes in order to achieve an optional payload integration process for the total spectrum of Shuttle Orbiter/Payloads.

TABLE 7.2 PAYLOAD INTEGRATION TRADE STUDY EVALUATION CRITERIA

CATEGORY	CRITERIA	BASELINE			OPTION 1 USER SITE ORIENTED			OPTION 2 LAUNCH SITE ORIENTED		
		WEIGHT FACTOR			WEIGHT FACTOR			WEIGHT FACTOR		
		$	T	R	$	T	R	$	T	R
PERSONNEL	AVAILABILITY SKILL MIX NUMBER OF PERSONNEL RELOCATION WITH PAYLOAD CREW DUPLICATION/DIFFERENT SITES/ UNION IMPACT									
	SUB-TOTAL									
FACILITIES	AVAILABILITY Δ FACILITY REQ. (NEW/MOD) FACILITY IMPACT: CLEANLINESS PROTECTION FROM HAZARDS ACCESS TO SOURCE OF TRANSPORT ENVIRONMENT LEVEL OF ASSEMBLY/PROCESSING REQ'D FACILITIES MAINTENANCE									
	SUB-TOTAL									
GSE	AVAILABILITY Δ GSE REQ. (NEW/MOD) GSE IMPACT LEVEL OF ASSEMBLY/PROCESSING REQ'D SIMULATORS REQUIRED HANDLING EQUIPMENT GSE MAINTENANCE									
	SUB-TOTAL									
OPERATIONS	DEGREE OF TESTING AND CHECKOUT (PHILOSOPHY) TRANSPORTATION AND HANDLING DEGREE OF SIMULATION PAYLOAD ACCESS FOR MAINTENANCE AND REPAIR SENSITIVITY TO PERTURBATIONS STANDARDIZATION OF INTERFACE VERIF. DEGREE OF SYSTEMS INTERFACE VERIF. SCHEDULE IMPACT/TIMELINES									
	SUB-TOTAL									
MANAGEMENT	PLANNING/SCHEDULING CONFIGURATION MANAGEMENT DOCUMENTATION MANAGEMENT GFE COORDINATION LOGISTICS ADMINISTRATION									
	SUB-TOTAL									
	GRAND TOTAL									

$ - ABSOLUTE COST
T - SCHEDULE TIME
R - RISK

NOTE: FOR EACH PAYLOAD, DETERMINATION OF $, T AND R REQUIRES DEVELOPMENT OF SUB-MATRICES APPLYING THE CRITERIA AGAINST EACH FUNCTION IDENTIFIED IN FFBD AND SUB-SEQUENT SUMMATION.

8.0 POTENTIAL APPLICATIONS FOR THE IVE

The results of the Shuttle/Payload Integration Analysis identified various potential applications for the IVE primarily associated with the verification of payload compatibility with the Shuttle. In order to realize the maximum potential for the IVE it is necessary to determine whether or not the IVE or portions of it may be used for other applications. As a first step, this study identified payload development and integration activities which require various degrees of knowledge of the Orbiter payload accommodations. Those activities involving the simulation of the Orbiter function were assessed for potential of the IVE to provide that function. The potential applications for the IVE to support the Shuttle/Payload development and integration process as identified in the study include:

Use as a Design Tool to Support Verification of

- Access GSE
- Clearances
- Power Distribution
- TV Camera Locations
- Payload Bay Lighting
- Payload Design/Development (at Interface)

Use as a Manufacturing Aid/Production Tool

- Cable and Fluid Line Mockup
- Flight Cable Buildup
- Flight Fluid Line Assembly
- Payload Structural I/F's in Payload Bay and Aft Flight Deck

Use for Procedures Development

- Payload Installation and Removal
- Checkout
- EVA
- Mission Timeline and Evaluation

Use for Training Aid

- Flight Crew-Payload Relation Operations
- Ground Crew

Additional analysis is required to determine the desirability of using the IVE for the above applications. Detailed requirements need to be defined, IVE design implications and associated costs/schedule data needs to be devloped, and trade studies performed to assess other techniques/equipment usage to accomplish the above functions.

9.0 IVE PROJECT DEVELOPMENT PLANS AND COST

Anticipating the potential schedule requiring initial payload interface verification equipment operational capability in support of KSC operations as early as mid 1978, project planning data was developed as necessary to support the initiation of the DDT&E phase of the IVE. The basic elements of the IVE project planning data include program plans, facility requirements, work breakdown structure (WBS), schedule and cost estimate. Emphasis was placed on the definition of the contractor management and configuration control plans (assuming Space Division as the contractor), development of the IVE manufacturing and assembly procedure and in-the-field IVE assembly and checkout procedure, WBS, IVE development schedule and cost estimate.

The IVE configuration management plan proposed by Space Division supplements the Space Shuttle Orbiter/System Integration, Contractor Configuration Management Plan, SD73-SH-0222. The closed loop CM system established by Space Division for the Orbiter would be used for the IVE providing management visibility and control from program go-ahead through design, production, test and product acceptance, and product support. Configuration control flows were developed for the following change implementations:

- o Level II NASA originated change request affecting payload interface
- o Orbiter originated change request affecting payload interface
- o IVE user/NASA originated change request affecting/not affecting the payload interface
- o Space Division request Level III not affecting payload interface

Manufacturing, assembly, testing and acceptance test and in-the-field assembly and readiness checkout procedures for the IVE were developed to facilitate maximum use of off-the-shelf hardware, to minimize manufacturing tooling and in-the-field support equipment for assembly, checkout and operational support. The IVE was designed as an independent, "stand alone" piece of hardware that is not integrated with any particular facility. Minimal facility support requirements include power source and drain, inert gas for fluid line purging and pressure leak test, floor anchor pads, optics (transit) and an overhead crane with a 10 ton rating (for IVE assembly). Facility ceiling, door and overhead crane heights are dictated by intended IVE/payload usage and may vary from one facility to the next (e.g. horizontal operation vs. vertical operation).

Assembly and checkout of the IVE at the user site (in-the-field assembly) is facilitated by the use of assembly tooling bench marks, scribe lines and a master alignment tool for locating all payload interface elements. Facility provided optics provide verification of IVE structural leveling and alignment. IVE operational maintenance will vary dependent upon its usage (horizontal or vertical position, size and type of payloads, frequency of use, out-of-tolerance utilization (accident, earthquake, floor settling, etc). Structural verification will be achieved through periodic visual inspection and optical leveling and alignment checks in conjunction with the master alignment tool for the payload interface. Frequency of maintenance checks will diminish as use data is generated for each facility set-up to establish configuration stability. Structural inspection and proof loading will be scheduled in accordance with prescribed safety regulations. IVE electrical subsystem self-checkout is provided as a built-in feature of the system. Maintenance and calibration of signal generation and signal monitoring equipment will be in accordance with established Orbiter GSE procedures.

The IVE project development schedule (Figure 9-1) was based on NASA provided IVE initial operational capability (IOC) dates and development lead times complementing the Space Division Orbiter program with respect to availability of Orbiter baseline payload accommodations data and manpower spread on a non-interference basis with the Orbiter schedule. This schedule avoids incurring unnecessary manpower peaking resulting in most cost effective IVE project development approach.

The IVE cost estimate summary in Table 9.1 reflects the master schedule and the WBS. Assumptions and guidelines governing the cost analysis include:

- o Cost FOB Downey, Calif
- o Cost does not include operational support (maintenance, training, handling and storage, spares, design mods, IVE activation at operational site, IVE operational services)
- o Provide engineering, fabrication, assembly, test and material cost breakdown to support DDT&E and unit costs
- o Use January 1976 $ base
- o IVE 2nd unit cost (horizontal IVE) equal 92% 1st unit if ordered concurrently, 105% if ordered in series

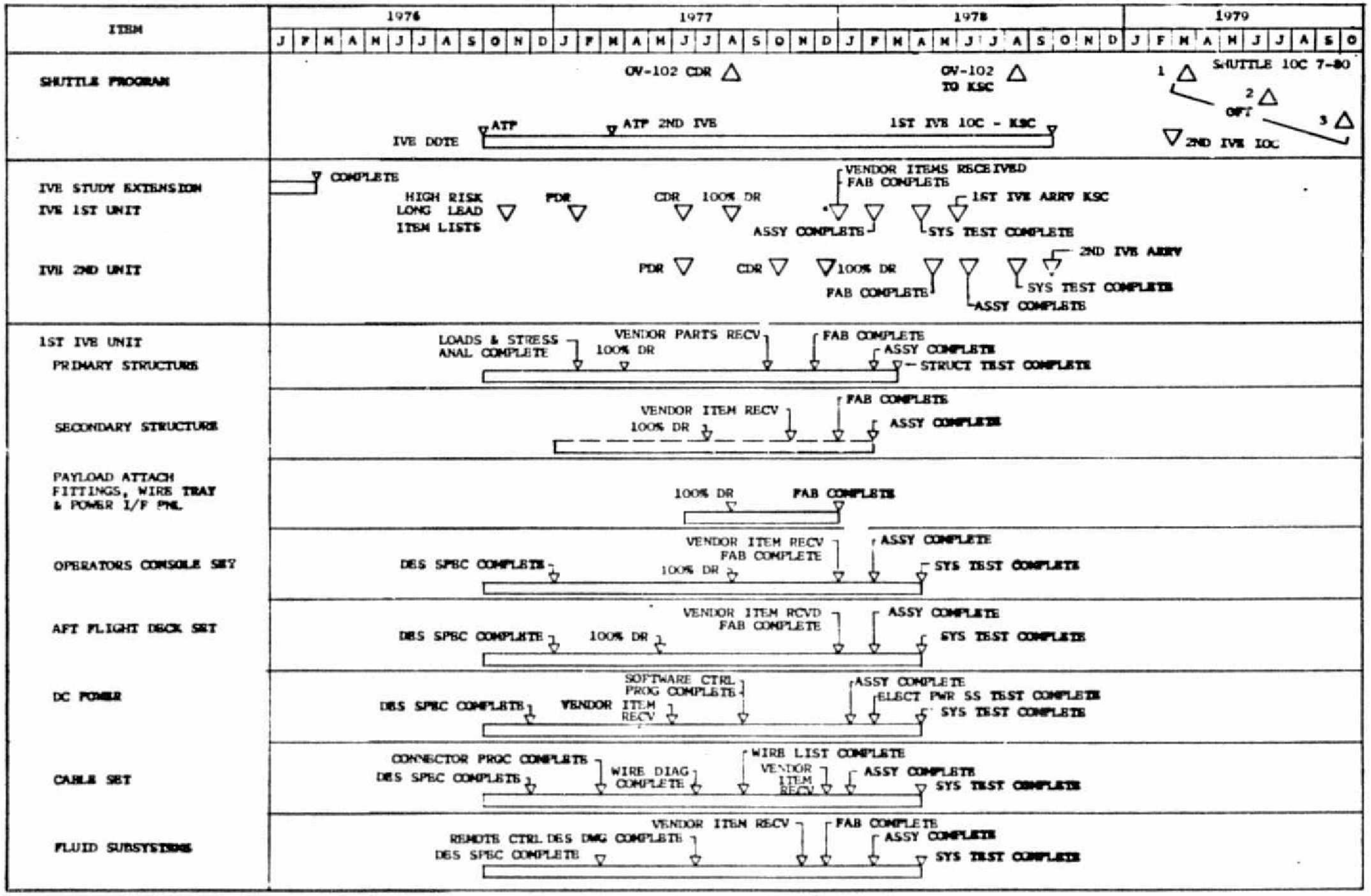

FIGURE 9-1 IVE MASTER SCHEDULE

TABLE 9.1 HORIZONTAL IVE COST ESTIMATE SUMMARY

	NON-RECURRING	1ST UNIT	TOTAL	2ND UNIT (105%)
STANDARD HORIZONTAL IVE				
o SYSTEM ENGINEERING MGMT	$270000	30000	300000	31500
o SUPPORT MGMT	90000	10000	100000	10500
o INTEGRATION AND ASSEMBLY	74950	24983	99933	26232
o STRUCTURE AND MECHANISMS	142785	241803	284588	253893
o OPERATORS CONSOLE UNIT	501535	489063	990598	513516
o AFT FLIGHT DECK SET	138731	389701	528432	409186
o DC POWER SET	20352	10716	31068	11252
o CABLE SET	48701	63691	112392	66876
o SOFTWARE	60000	-	60000	-
o STRUCTURAL TEST	5994	13468	19462	14141
o SYSTEM TEST	23772	35814	59586	37605
o ACCEPTANCE TEST	21175	56098	77273	58903
o SUPPORT EQUIPMENT	13271	33000	46271	34650
o DATA				
SUBTOTAL	1411266	1398337	2809603	1468254
10% MARGIN	141127	139834	280960	146825
STANDARD HORIZONTAL IVE TOTAL	1552393	1538171	3090563	1615079
ONE SET OPTIONAL EQUIP (10% MARGIN)	475811	234165	709976	245873
TOTAL	2028204	1772336	3800539	1860952

OPTIONAL EQUIPMENT ELEMENTS MAY BE TAILORED TO USER NEEDS

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10.0 CONCLUSIONS AND RECOMMENDATIONS

10.1 CONCLUSIONS

The Horizontal IVE concept developed in this study represents a first attempt to define a standard integration device to support the verification that a payload/cargo is compatible with the Shuttle/Orbiter prior to on-line payload installation into the Orbiter. The initial intent of the study was to define a low cost device capable of verifying Orbiter-to-payload interface compatibility. During the study the performance requirements were expanded which led to the development of the IVE as an integration device capable of verifying not only interface compatibility but also to support payload functional performance and mission simulation for STS cargo as well as single payloads.

The IVE is a stand alone non-facilitized device which verifies Orbiter-to-cargo (payloads) interfaces within the following limitations imposed due to high cost, impact on facility, and duplication of existing under-development, or planned capabilities within the STS program: EMI/EMC restricted to payload conducted interference (Orbiter sources not included), software verification limited to timing and sizing checks (complete verification requires an Orbiter General Purpose Computer), payload bay environment simulation limited to payload active thermal control (dynamics, temperature,humidity and purge capability not included), passive RMS (complex facility interface and/or driver/control mechanism required for viable simulation), and non-active fluid interfaces (restricted to pressure leak checks). The IVE design does not preclude the upgrading of its capability to alleviate the above limitations at additional cost.

At the time this study was conducted, a complete set of payload integration requirements did not exist. The IVE concept reflects the requirements as specified in Section 5.0 of this Volume which originated from NASA, JSC (assumed role of STS integrator to define requirements), GSFC (representing free flyer and multi-mission spacecraft requirements), MSFC (Spacelab requirements) and KSC (launch site requirements).

The following conclusions resulted from this study:

1. The IVE can be used to support payload development, functional checkout, acceptance testing and mission flight simulation.

2. The IVE may be used to support development and verification of payload ground operational procedures and

operational timelines for payload installation and removal, and access when payload is installed in Orbiter.

3. The IVE may be used as a design aid tool with respect to location of payload lighting and camera locations, payload cabling and fluid line routing and their attachment.

4. The IVE may support ground and flight crew training.

5. A common structural design approach for horizontal and vertical IVE operation is feasible with minimal penalty.

6. IVE electrical subsystem design utilizing commercial test equipment with a minimum of Orbiter non-flight qualifiable design hardware provides (1) IVE maximum operational flexibility, (2) an IVE configuration independent of Orbiter flight hardware and its scheduled availability, and (3) least cost.

7. The IVE as designed is a high fidelity replica of the Orbiter payload accommodations providing a standard interface and is not dependent upon payload design. As such, the IVE design provides a inherent operational flexibility to support payload integration for new missions (and associated spacecraft) not presently defined in the STS mission model. The IVE modular design also allows for the most cost effective approach to expand the IVE capabilities on an as needed basis, e.g., tailor the IVE configuration to the user needs in a time phased basis to support the existing (at the time) Space program.

10.2 RECOMMENDATIONS

The following tasks are required to be accomplished in order to provide a firm basis for initiating development of payload integration devices:

1. Requirements - An STS systems requirements analysis is required representing all STS system elements (payloads, Orbiter and launch site). The general requirements governing the IVE study (specific and assumed) represented the best available information.

The STS program development has matured since the IVE study inception. Specific cargo/payload integration requirements need to be developed for the launch sites and payload user site. These requirements must reflect a division of payload integration activities between the launch site and payload developer sites such that a cost effective STS payload integration process is accomplished.

2. Requirements Sensitivity Analysis - The payload integration requirements must reflect the anticipated "real world" Orbiter cargo consisting of mixed payloads. A requirements sensitivity analysis is required to assess impact on varying integration processes with respect to site location, traffic flows, traffic density and identify critical requirements driving integration equipment design and cost.

3. STS System Operation Performance Trades - STS system performance trades need to be performed to verify optional system operations of the STS. Trade impact of various traffic models on payload integration equipment requirements (type, inventory, facilities including relaxing the Orbiter turnaround times) to determine the lowest cost per flight commensurate with anticipated future space budgets.

4. IVE Potential Applications - Conduct an intensive investigation of the degree of commonality/integration of the cargo/payload integration devices with the workstands at the launch site, payload handling and transport devices and GSE/Test equipment at launch site and payload developer sites. Also investigate other applications of the IVE or CITE (NASA/KSC version of IVE-Cargo Integration Test Equipment) to determine desirability of a common device to support payload ground support operations (procedures and timeline development and verification), flight crew training and other potential applications identified in Section 8.0 of this volume.

   Design commonality of STS payload GSE, Orbiter payload integration devices, training aids, etc., may reflect significant savings over the operational era of the STS program. Significant cost contributors to the operational phase of the STS are configuration control,

operations and logistics (inventory and handling) management. As hardware design commonality on a program increases, the operational costs decrease due to savings in the reduced level of program management operations for configuration management and logistics support for a fewer number of equipment items.

5. IVE Design Evaluation - Reassess applicability of the IVE design to meet updated set of STS payload integrations requirements (include DoD requirements). Identify delta design impact and associated costs and schedule impact.

6. Payload Integration Device (IVE) - Design of payload integration equipment must incorporate flexibility in performance to satisfy the ever changing requirements as the STS program matures. Consideration must be given to modular designs providing a systematic, cost effective method for updating payload integration equipment capability at respective user locations on a time schedule "in tune" with the STS program requirements. Flexibility of performance must be inherent in the design of the payload integration equipment to respond to new space missions (presently unknown) and everchanging responsibilities and requirements of payload users during the STS program operational life.